Beef Research Program

Progress Report No. 1

Roman L. Hruska
U.S. Meat Animal Research Center

In cooperation with
University of Nebraska College of Agriculture
The Agricultural Experiment Station

Agricultural Reviews and Manuals
Agricultural Research Service
U.S. Department of Agriculture

ARM-NC-21

April 1982

Published by Agricultural Research Service
North Central Region
U.S. Department of Agriculture
2000 W. Pioneer Parkway
Peoria, IL 61615

Library of Congress ISSN 0193–3787

CONTENTS

ROMAN L. HRUSKA U.S. MEAT ANIMAL RESEARCH CENTER[1]

Overview on Center

The Roman L. Hruska U.S. Meat Animal Research Center (MARC) was authorized by Congress on June 16, 1964, thereby creating a single facility that provides an unusual opportunity for making major contributions to the solution of problems facing the U.S. livestock industry. Development of the 35,000-acre facility started in the spring of 1966 and is continuing at the present time. Phase I construction, consisting of an office-laboratory building for intensive investigations, was completed in January 1971. These facilities provide a physical plant for 42 scientists and about 200 support personnel. Phase II construction, consisting of the Meats Research Laboratory and Agricultural Engineering Building, was completed in October 1977. It provides a physical plant for 25 scientists and about 60 support personnel. Phase III construction will provide facilities for a comprehensive research program of producing, harvesting, handling, storing, and using forages in livestock production systems. Approximately 35 additional scientists and 65 support personnel will be required for this phase. Currently, one-third of the scientific staffing is completed.

Approximately one-half of the research program is devoted to beef cattle, one-fourth to sheep, and one-fourth to swine. Current research program objectives require breeding-age female populations of approximately 7,000 cattle (20 breeds), 5,000 sheep (9 breeds), and 500 swine litters (8 breeds) per year.

The research program at the Center is organized on a multidiscipline basis and is directed toward extending investigations into new areas not now being adequately studied to provide new technology to increase quantities of palatable, wholesome, and nutritious beef. We are planning and conducting from the basic cellular level, examining the very fundamental biology of life processes to the animal level, and examining environmental and genetic influences on beef quantity, composition, and quality. The aim of the research program is to provide basic knowledge of the fundamental processes of biology as a basis for developing new technology with production and consumer application.

The current program includes research in genetics and breeding, nutrition, reproduction, agricultural engineering, meats, production systems, and crop residue-forage utilization. The research program complements research conducted elsewhere by the U.S. Department of Agriculture (USDA) and is cooperative with the Nebraska Agricultural Experiment Station and other Land Grant university agricultural experiment stations throughout the country. The program is also designed to complement existing domestic and international research programs in developing beef cattle production technology.

---

[1]Agricultural Research Service, U.S. Department of Agriculture, the University of Nebraska, and other cooperating Land Grant Universities.

Overview on the Beef Cattle Research Program

MARC's beef cattle research program places the highest priority on developing technology capable of having an immediate and major impact on the beef cattle industry. Although the program is largely oriented towards fundamental research, emphasis is placed on the generation of technology that can be practically implemented by small farmers and commercial beef cattle producers alike within a relatively short time frame. Because of the uniqueness of the Center's resources, research is being conducted on a "conception to consumption" basis with beef cattle.

Currently, we have 18 scientist "equivalents" conducting research in the beef cattle program at MARC. They are working in 19 primary thrust areas and have 44 experiments under way. In addition, they are coworkers on six major projects away from MARC. Also, MARC has an active predoctoral, postdoctoral, and visiting scientist program, which supports the beef cattle research program.

This report represents a cross section of our beef cattle research program at the present time. Since some of the projects from which results are reported are still in progress, the preliminary nature of some of the results must be recognized. However, it is our opinion that information useful to the industry should be provided at the earliest possible time. Progress reports of this nature will be released periodically to make current results available to the industry. For convenience, the research program is reviewed on a discipline basis in this report with problem areas listed under the disciplinary unit that is taking the lead on research programs in each specific problem area.

Robert R. Oltjen

Robert R. Oltjen, Director
Roman L. Hruska U.S. Meat
Animal Research Center

SIXTEEN YEARS OF SELECTION FOR WEANING WEIGHT, FINAL WEIGHT, AND MUSCLING SCORE IN HEREFORD CATTLE

Robert M. Koch,[1] Larry V. Cundiff, and Keith E. Gregory

Introduction

Selection is the primary force for changing average genetic composition of herds, breeds, or species. Individual changes from one generation to the next associated with selection are usually small. In time, however, the change can be dramatic.

Selection is deciding which bulls and cows get to become parents and how many offspring we allow them to have. Both the will of man and the will of nature are directive forces in selection. Rate of progress from selection is determined by (1) average selection differential of parents for all traits under selection, (2) heritability of traits, (3) genetic correlations between traits, and (4) interval between generations of parents.

Selection differential is the difference in performance of selected sires and dams compared with the average of the unselected group from which they came.

Heritability is the fraction of the observed differences between animals caused by average genetic differences.

Genetic correlation is the average genetic association between traits.

Interval between generations is the average age of sires and dams when offspring are born (which in our herd was 4.4 years).

Procedure

An experiment to study selection effects in beef cattle was started in 1960 with the Hereford herd at the Fort Robinson Beef Cattle Research Station, Crawford, Nebr. Foundation cows came from 14 different herds and were the progeny of 130 different bulls. Forty-two sires were used in the formative years.

In 1960, about 325 cows were randomly divided into three lines. Weaning weight, standardized to 200 days and adjusted for age of dam, was the selection criterion to pick replacement bulls and heifers in one line (WWL). Adjusted final weight, at 424 days for bulls and 500 days for heifers, was the selection criterion in a second line (FWL). In the third line, selection was based on an index giving equal emphasis to adjusted final weight and a muscling score (IXL). Selected bulls and heifers born in 1960 produced the first selected generation in 1963.

Each line was expanded and maintained at about 150 cows and 6 sires for any given year. Two or three bulls, selected on their respective criteria, were retained in each line each year. Bulls were used first as 2-year-olds and continued in service for 2 or 3 years. Lines were maintained at 150 cows by retaining 25 or more bred heifers per line and removing an equal number of cows. Cows were removed according to criteria in the following priority.

(1) Not pregnant when examined at weaning time,
(2) Serious unsoundness,
(3) Failure to raise a live calf, and
(4) Oldest age.

The cattle were transferred to MARC in 1971. A *control* line was established at that time by breeding 225 of the remaining foundation cows with semen stored from foundation bulls. This line serves as a base of comparison for selected and unselected cattle.

Selection Applied

Selection differentials of replacement sires were calculated by expressing records as deviations from the average of their respective year line-sex group.

For example, the two sires selected in the weaning weight line from the 1966 calf crop had selection differentials as shown in Table 1.

In a typical year, there were 64 to 75 bulls in a line-year group at weaning. Of these, 60 to 70 bulls completed postweaning performance in sound condition. Two or three of these bulls were selected on the basis of their weaning weight (WWL) or final weight (FWL). In the IXL, the deviations for final weight and muscle score were combined in such a manner that the bulls with the largest average deviation (index) were selected. Mean selection differentials of selected sires are shown in Table 2.

Selection differentials in Table 2 emphasize that primary selection for one trait may lead to significant selection differentials in other traits because of natural correlation between traits or chance. Selection differentials of all traits and their normal relationships were considered in interpreting the amount of total selection practiced and response expected in each trait.

Selection of replacement heifers in each line was similar to selection procedures for bulls. All remaining heifers were exposed to bulls during the summer breeding season. On the average, 90% of the heifers became pregnant, and selection of replacements was restricted to the 25 to 35 "best" pregnant heifers. Selection differentials of the replacement heifers are shown in Table 2.

Sires and dams contribute equally to the average genetic makeup of offspring. Comparative size of bull and heifer selection differentials illustrates the often quoted phrase that "most of the selection intensity must come from bull selection." In the case of weaning weight in WWL, 80% of the total selection was due to bulls, and for final weight in FWL, 86% of the selection was due to bulls.

Total Selection And Response

The total mid-parent selection differentials (average of sires and dams), average performance for the years 1977

Table 1.—Selection differentials of sires in weaning weight line, 1966

Trait	Avg 1966, WWL bulls	Record	Selection differentials	Record	Selection differentials
Birth wt ____ lb	77	64	-13	89	12
Wean. wt __ lb	465	518	53	541	76
Yrlg. wt ____ lb	996	1081	85	1037	41
Muscle score	81	82	1	81	0

Table 2.—Selection differentials of selected sires and dams[1]

Selection	Birth weight		Weaning weight		Final weight		Muscle score	
	Sires	Dams	Sires	Dams	Sires	Dams	Sires	Dams
Weaning wt	7.8	1.6	75	19	110	21	1.2	0.4
Final wt	6.6	1.5	57	12	140	19	1.6	0.4
Index	7.0	2.0	54	14	116	25	3.6	0.4

[1]From Buchanan, D.S. 1979. Selection for growth and muscle score in beef cattle. Ph.D. Thesis. University of Nebraska, Lincoln 160 p.

[1]Robert M. Koch is a University of Nebraska–Lincoln research geneticist stationed at MARC.

to 1979, selection response, and realized heritability are shown in Table 3.

Total selection from 1963 to 1978 is not as large as might be anticipated from looking at the selection in Table 2 because many calves born in the years 1961 to 1970 had foundation parents with zero selection differentials.

Selection responses, calculated from the differences between the performance of selected and control lines, show significant increases in all traits over the control.

Realized heritability represents that fraction of parental selection differentials due to differences in average genetic merit and recovered in terms of increased (or decreased) performance of offspring. Realized heritabilities in Table 3 are the ratios of selection responses to midparent selection differentials.

Birth weight increased in all lines because of direct selection as a part of weaning or final weight and from correlated response associated with gain from birth to weaning or final ages. We estimate that the increase in birth weight could be reduced by 30% if all growth selection was directed to gain after birth instead of selecting for total weaning or final weight.

Selection response in weaning weight was highest in WWL and IXL. Although selection for weaning weight in IXL was significantly lower than in WWL, the response was about equal or higher, indicating a higher realized heritability. The slightly lower heritability for weaning weight in FWL could be due to chance or to unknown negative factors associated with the intense selection for postweaning gain.

The highest response in final weight was in IXL even though more selection was applied in FWL.

The greatest response in muscle score was in IXL, which also had the largest selection differential.

Correlated Response To Selection

As birth weight increased in selected lines, percentage of first-calf heifers requiring assistance at calving increased. Average birth weights and percentages of assisted births for males and females are shown in Table 4. A significantly higher percentage of heifers in the selected lines required assistance compared to the control line. Also, more heifers producing male calves required assistance than heifers producing female calves. All of the increased assistance among male calves could not be accounted for by higher birth weights. Possibly the extra difficulty is due to shape or bone structure.

Efficiency of gain is largely determined by differences in composition of gain produced, differences in weight maintained, and number of days weight is maintained. Average daily gain of bulls during the postweaning gain test, and the efficiency of gain, expressed as pounds of gain per megacalorie of metabolizable energy consumed for the years 1972 through 1978, are shown in Table 4. The evaluation was made over a weight constant interval that averaged 500 to 900 lb. Selected line bulls gained more rapidly and had better efficiency of gain than the control line bulls. Average feed consumption per day did not differ significantly among control and selection line bulls.

No measurements of composition of gain were obtained. However, data from steers produced in 1963 to 1970 indicated that genetic increase in rate of gain is associated with slight increases in lean and decreases in fat percentages at equal weights. The more rapid gains of the selection lines meant that they took 10 to 15 days less to gain the 400 lb and, thus, had fewer days of weight maintenance.

The evidence from this experiment indicates selection is effective in making slow (½ to ¾ percent per year) but steady changes in growth traits. Growth measured at birth and during the postweaning period was more highly heritable than growth from birth to weaning. Growth in one period was positively genetically correlated with growth in other periods. The genetic increase in growth rate was associated with increased calving difficulty and with increased efficiency of gain.

Table 3.—Total midparent selection, average performance, selection response, and realized heritability

Trait and line[1]	Midparent selection differential	Average performance 1977 to 1979	Selection response	Realized heritability
Birth weight, lb:				
Control	0	76.6	0	0
WWL	16.2	83.7	7.1	.44
FWL	14.7	82.7	6.2	.42
IXL	14.5	85.9	9.3	.64
Weaning weight, lb:				
Control	0	397.8	0	---
WWL	163	430.0	32.2	.20
FWL	116	418.2	20.5	.18
IXL	116	431.2	33.6	.29
Final weight, lb:				
Control	0	836.9	0	---
WWL	220	902.8	65.9	.30
FWL	270	910.7	73.9	.27
IXL	245	934.0	97.2	.40
Muscle score:				
Control	0	80.9	0	---
WWL	2.6	81.4	.5	.19
FWL	3.5	81.3	.4	.11
IXL	6.7	82.1	1.2	.18

[1]WWL = weaning weight line; FWL = final weight line; IXL = index line.

Table 4.—Calving assistance in 2-year-olds, postweaning daily gain, and efficiency of gain through a weight constant interval (400-900 lb)

	Calving assistance				Postweaning gain test		
	Males		Females				
Line[1]	Birth wt (lb)	Percent assisted	Birth wt (lb)	Percent assisted	Daily gain (lb)	Gain per Mcal ME	Days fed
Control	71	50	66	19	2.24	0.113	176
WWL	78	58	73	38	2.40	0.119	165
FWL	78	64	72	43	2.43	0.122	163
IXL	82	77	75	39	2.47	0.121	161

[1]WWL = weaning weight line, FWL = final weight line; IXL = index line.

EFFECTS OF HETEROSIS IN HEREFORD, ANGUS, AND SHORTHORN ROTATIONAL CROSSES

Larry V. Cundiff,[1] Keith E. Gregory, and Robert M. Koch

Introduction

Seedstock breeders of poultry and of many plants, such as corn, may use static systems of mating that produce sufficient hybrids for complete use of heterosis in commerical production. Use of heterosis in these species can be maximized because only a small proportion of the total population is required for seedstock production. Complete use of heterosis is more difficult in cattle because of their relatively low reproductive rate and long generation interval, which overlaps from one year to the next. However, this difficulty does not preclude the use of a high level of heterosis in commercial beef production. Systems of crossbreeding can be used that maintain significant levels of heterosis from one generation to the next. Crossbreeding systems can also provide for use of additive genetic variation between breeds to combine and match characteristics of breeds with feed and other production resources and with market requirements.

Effects Of Heterosis

An extensive crossbreeding experiment involving Herefords, Angus, and Shorthorns was initiated at the Fort Robinson, Nebr., Beef Cattle Research Station in 1957. In 1972, the project was transferred to MARC, where the evaluation of heterosis through advanced generations of systematic crossbreeding was completed in 1976. Heterosis has been evaluated by comparing crossbreds with straightbreds for a comprehensive series of traits of economic importance in beef production. We conducted the experiment in three phases.

In phase I, when 476 crossbred calves were compared with 447 straightbred calves, weaning weight per cow exposed was 8.5% or 29 lb greater for straightbred cows raising F_1 crossbred calves than for straightbred cows raising straighbred calves. This advantage was caused by a 3% increase in calf crop weaned, resulting from increased survival of crossbred calves from birth to weaning, and by a 4.6%, or 19 lb/calf, increase in weaning weight of crossbred calves.

In phase II, crossbred cows were compared with straightbred cows when they were both raising crossbred calves by the same sires of a different breed. For example, to evaluate maternal heterosis in Hereford-Angus crosses, we compared performance of Hereford-Angus and Angus-Hereford cows with that of Hereford and Angus cows when the cows in all four groups were mated to the same Shorthorn bulls. In phase II, a total of 687 matings of crossbred cows and 560 matings of straightbred cows were made over six breeding seasons. Actual weaning weight was 14.8% or 51 lb greater per cow exposed to breeding for crossbred cows than for straightbred cows. This advantage was caused by a 6.5% increase in calf crop weaned, reflecting greater first-service conception and final pregnancy rates of crossbred cows, and by a 4.3%, or 19 lb/calf, increase in weaning weight, reflecting greater and more persistent milk production by crossbred cows.

When the advantages of individual heterosis on survival and growth of F_1 crossbred calves (phase I) and the advantage of maternal heterosis on reproduction and maternal ability of crossbred cows (phase II) are combined, weight of calf weaned per cow exposed to breeding is increased 23%, or about 80 lb (Fig. 1). More than 60% of the increased performance from heterosis was attributable to crossbred cows.

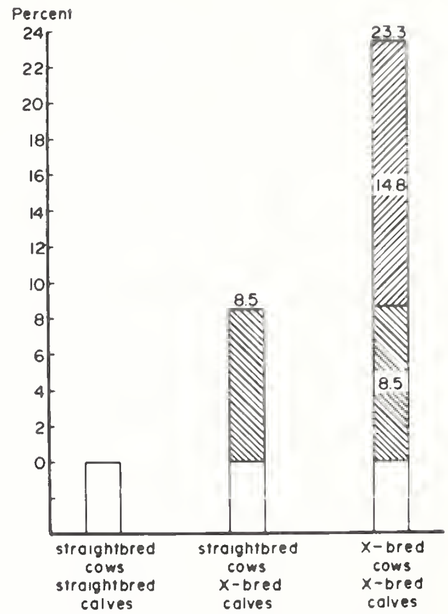

Figure 1.—Cumulative heterosis effects for pounds of calf weaned per cow exposed to breeding.

Evaluation Of Rotational Crossing

Rotational systems of crossbreeding have been used in commercial swine production for a number of years. The systems most commonly being used in commercial beef production are diagrammed in Figure 2.

The two-breed rotation is initiated by mating cows of breed A to bulls of breed B. Heifers resulting from these matings are, in turn, mated to bulls of breed A for their entire lifetime. In the next generation,

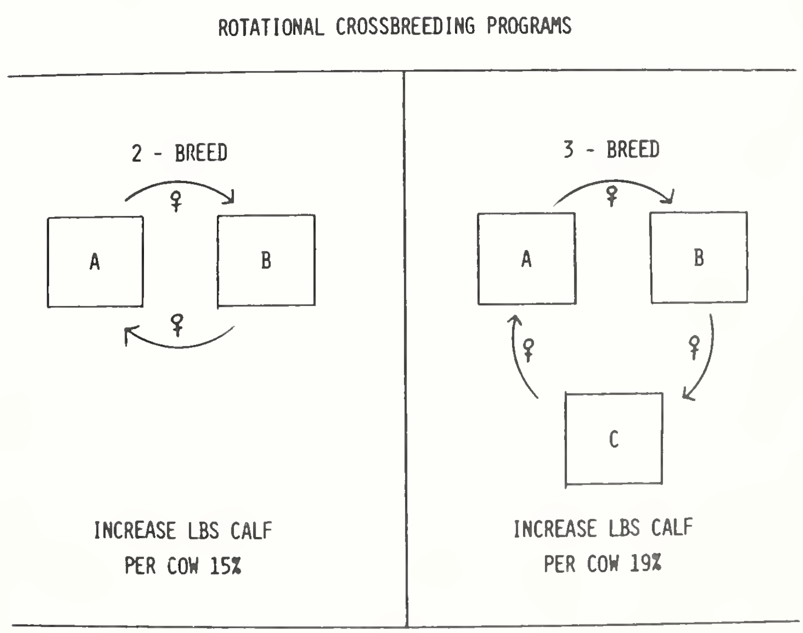

Figure 2.

[1]Larry V. Cundiff is a research leader (Breeding and Genetics) at MARC.

heifers sired by breed A are mated to bulls of breed B, generation after generation. Thus, at least two breeding pastures are required for this system, and it is necessary to identify heifers by breed of their sire.

In the three-breed rotation, the pattern is the same except that a third breed is included in the rotation. In a three-breed rotation, at least three breeding pastures are required, and it is necessary to identify heifers according to the breed of their sire.

Rotational systems maintain a substantial level of heterozygosity from one generation to the next. On the average, in the two-breed rotation, two-thirds of the genes of the cow are of the breed of her sire, and one-third is of the breed of her grandsire, the latter being the same as the breed to which the cow is mated. Thus, the level of heterosis expected from a two-breed rotation is on the average two-thirds, or 67%, of the maximum level expected when an F_1 cow is mated to sires of a third breed. The three-breed rotation sustains a higher level of heterosis because the relationship between cows and bulls being mated is more remote. The three-breed rotation sustains an average level of 86% of the maximum heterozygosity realized in three-breed cross calves out of F_1 cows.

Phase III of the Fort Robinson heterosis experiment was designed to determine the level of heterosis that can be maintained from one generation to the next by two- and three-breed rotations among the Hereford, Angus, and Shorthorn breeds and to determine whether or not the level of individual and maternal heterosis maintained by rotational crossing is proportional to expected levels of heterozygosity relative to F_1 crosses for both individual and maternal traits. Phase III of the study was conducted at MARC, following transfer of cattle from the Fort Robinson beef cattle research station to Clay Center in 1972.

The mating plan and the number of matings made in phase III of the experiment are shown in Table 1. The phase II cows, consisting of straightbred Hereford, Angus, and Shorthorn, and all possible reciprocal F_1 crosses, were used to produce the first generation of phase III. Straightbred calves were produced to provide a basis for comparison for the two- and three-breed rotation systems. The F_1 reciprocal-cross cows were mated to produce either backcross calves (to set up the two-breed rotations) or three-way cross calves (to set up the three-breed rotations). Four calf crops were produced in generation 1 of phase III, with the final calf crop produced in 1972.

Heifers produced in generation 1 of phase III were kept to evaluate heterosis maintained in two-breed and three-breed rotations relative to straightbreds. Matings were made such that contemporary comparisons between controls consisting of straighbred Herefords, Angus, and Shorthorns could be made with all possible two-breed rotations and the three-breed rotation in all possible sequences when all matings were made with the same purebred sires. Five calf crops were produced. The final calf crop was produced in the spring of 1975.

The expected genetic differences between two- and three-breed rotation crosses and straightbred controls in the first and second generation of phase III are summarized in Table 2. Backcross calves are expected to express only one-half of the individual heterozygosity of an F_1 calf (estimated from phase I to be 8.5% for weaning weight per cow exposed to breeding) and all of the maternal heterosis (estimated from phase II to be 14.8%) for a total increase of 19% more weaning weight per cow exposed than with straightbreds. These expectations result for backcross calves because one-half of the dam's inheritance (chromosomes) is of the same breed as the sire of the calf and because the dam is an F_1 cow. The three-way cross produced to set up the three-breed rotation expresses maximum individual and maternal heterosis (23%). In the second generation of phase III, two-breed rotation calves were expected to express 75% of the individual heterosis of an F_1 calf (8.5% in phase I) and, being raised by a backcross, 50% of the maternal heterosis (14% in phase II). In the second generation of phase III, three-breed rotation calves were expected to express 75% of the individual heterosis and 100% of the maternal heterosis. These expectations are based on the hypothesis that heterosis retention is proportional to level of heterozygosity retained and is due to the dominance effects of genes. Actual observed results could fall short of the expectations if epistatis or

Table 1.—Experimental design and number of matings in phase III of heterosis experiment with Herefords, Angus and Shorthorns[1]

Generation 1 (4 calf crops, 1969-1972)			Generation 2 (5 calf crops, 1971-75)				
Sire	Dam	Number of matings	Dam	H	A	S	Total
				Straightbred controls			
H	H	131	H	94			94
A	A	137	A		153		153
S	S	163	S			164	164
		431					411
				2-breed rotation			
H	HA	42	H•HA		34		34
H	AH	34	H•AH		26		26
A	HA	41	A•HA	52			52
A	AH	34	A•AH	42			42
		151					154
H	HS	24	H•HS			35	35
H	SH	39	H•SH			29	29
S	HS	23	S•HS	17			17
S	SH	39	S•SH	33			33
		125					114
A	AS	26	A•AS			36	36
A	SA	40	A•SA			55	55
S	AS	26	S•AS		16		16
S	SA	42	S•SA		43		43
		134					150
All 2-breed		410					418
				3-breed rotation			
H	AS	25	H•AS		21	20	41
H	SA	44	H•SA		21	27	48
A	HS	25	A•HS	15		15	30
A	SH	39	A•SH	38		32	70
S	HA	42	S•HA	26	26		52
S	AH	35	S•AH	11	13		24
All 3-breed		210					265

[1]H = Hereford, A = Angus, S = Shorthorn

effects from many combinations of genes are important in causing heterosis.

Results from preliminary analyses on percentage of calf crop weaned, weaning weight, and weight of calf weaned per cow exposed for the first generation of phase III are shown in Table 3. Calf crop was 8% greater for three-way crosses out of F_1 dams than for straightbreds, which compares closely to the expected 9.4% advantage resulting from combining effects of individual heterosis (3%) found in phase I and maternal heterosis (6.4%) found in phase II. The 25% advantage in weight of calf weaned per cow exposed is close to the cumulative advantage of 23% expected when comparing three-way crosses out of F_1 cows with straightbreds.

Backcross calves are expected to show half of the heterosis expressed by F_1 calves for individual heterosis (phase I) and all of the maternal heterosis (phase II) since they are out of F_1 dams. Results shown in Table 3 are close to expectations for all three traits and are especially close for weight of calf weaned per cow exposed.

Table 3 shows preliminary results for percentage of calf crop weaned, weaning weight, and weaning weight per cow exposed from the second and final generation of phase III. Results exceed expectations slightly in both two- and three-breed rotations for all three traits. In the second generation, although the performance of two- and three-breed rotations are both higher than expected relative to straightbreds, the difference between the two-breed *versus* the three-breed rotation does indicate that the loss in heterosis is linearly associated with the loss in heterozygosity (for example, in the second generation, the expected difference and the observed deviation from straighbreds is half again larger for the three-breed rotation than for the two-breed rotation).

Table 2.—Expected difference between 2- or 3-breed rotation crosses and straightbred controls in first and second generation of phase III in heterosis experiment[1 2]

Contrast	H^I	H^m	Increase in weaning weight per cow exposed
First generation:			Percent
Backcross vs. St-Bred	½	1	19.0
3-way cross vs. St-bred	1	1	23.3
Second generation:			
2-Breed rotation vs. St-bred	¾	½	13.8
3-Breed rotation vs. St-bred	¾	1	21.2

[1]H^I = individual heterosis, H^m = maternal heterosis.
[2]Based on expection that H^I = 8.5 percent, H^m = 14 84 percent

Conclusions

Results with Herefords, Angus, and Shorthorns indicate that heterosis can increase pounds of calf weaned per cow in the breeding herd by 23%. More than half of this advantage depends on use of crossbred cows. Compared to straightbreeding, rotational systems of crossbreeding sustain high levels of heterosis from one generation to the next. Greater heterosis is maintained by a three-breed rotation than by a two-breed rotation. The increase in heterosis observed for the three-breed rotation compared to the two-breed rotation is proportional to differences in expected heterozygosity relative to F_1 crosses.

Table 3.—Effects of heterosis in rotational systems of crossbreeding

Item	Control	Rotational Systems 2-Breed	Rotational Systems 3-Breed
Mating type:		FIRST GENERATION	
Cow	St-bred	F_1 cross	F_1 cross
Calf	St-bred	Backcross	3-way cross
No. matings	431	410	210
Calves weaned .... %	75	79	83
200-day wt .... lb	433	477	488
Weaning wt/cow exposed:			
Weight .... lb	324	378	405
Difference .... lb	0	54	81
Observed ratio	100	119	125
Expected ratio	100	110	123
Mating type:		SECOND GENERATION	
Cow	St-bred	1st Backcross	3-way cross
Calf	St-bred	2nd Backcross	1st Backcross
No. of matings	367	388	239
Calves weaned .... %	69	78	84
205-day wt .... lb	417	454	463
Weaning wt/cow exposed:			
205-day wt/cow .... lb	284	353	384
Difference .... lb	0	69	100
Observed ratio	100	124	135
Expected ratio	100	114	212

HETEROSIS AND BREED MATERNAL AND TRANSMITTED EFFECTS IN BEEF CATTLE

Keith E. Gregory,[1] Larry V. Cundiff, and Robert M. Koch

Introduction

Heterosis has been shown to have important effects on most economic traits of beef cattle. This is a report of the results from the first phase of an experiment designed to evaluate heterosis and breed maternal and transmitted effects on economic traits of beef cattle and involves some combinations of breeds not previously included in crossbreeding experiments. Results are reported on preweaning traits, growth rate and puberty in females, growth traits in steers, and carcass traits of steers produced in an experimental design that included the straightbreds and all possible crosses of the Red Poll, Brown Swiss (European and domestic), Hereford, and Angus breeds.

Preweaning Traits

Preweaning traits were analyzed on 1,207 calves born and 1,151 calves weaned. Effects of heterosis were significant for birth weight, calf crop weaned, preweaned average daily gain, and 200-day weight. Cows producing crossbred calves weaned 7.4% more weight per cow calving than cows producing straightbred calves. The four breeds did not differ in breed mean heterosis for the traits analyzed. Calves with Red Poll and Brown Swiss dams averaged 5 lb heavier at birth and 77 lb heavier at 200 days than their reciprocal crosses with Hereford and Angus dams. Breed maternal effects favored the Brown Swiss and Red Poll breeds over the Hereford and Angus breeds for traits associated with growth rate.

Breed transmitted effects showed the four breeds ranking in order (high to low) of Brown Swiss, Angus, Hereford, and Red Poll for traits associated with growth rate. The four breeds in crosses ranked in order (high to low) of Brown Swiss, Red Poll, Angus, and Hereford for traits associated with growth rate. The four breeds in crosses did not differ significantly from each other in perinatal mortality and calf crop weaned.

Growth Rate And Puberty In Females

Postweaning growth rate and puberty data were analyzed on 536 females. Effects of heterosis on growth rate were expressed on average daily gain from 200 to 400 days, 400-day weight, and 550-day weight. Most of the effects of heterosis on growth rate were expressed on average daily gain from 200 to 400 days. Crossbreds were 15 lb heavier and 9.4 days younger than straightbreds when puberty was observed.

Reciprocal cross differences averaged 74, 69, and 61 lb for 200-, 400-, and 550-day weight, respectively, in favor of females with Red Poll and Brown Swiss dams in crosses with Hereford and Angus. Breed maternal effects showed Brown Swiss and Red Poll breeds generally superior to Hereford and Angus breeds in most traits evaluated.

The Brown Swiss breed showed significantly higher breed transmitted effects than the other breeds for growth traits. Red Poll, Hereford, and Angus breeds did not differ greatly from each other in breed transmitted effects for growth traits; differences generally favored the Angus breed. Breed transmitted effects for weight at puberty showed the Red Poll breed reaching puberty at significantly lighter weight than the three other breeds.

The Brown Swiss breed in crosses was significantly heavier at 200, 400, and 550 days than crosses of the three other breeds, and the Red Poll, Hereford, and Angus breeds in crosses did not differ significantly from each other in 550-day weight. The Red Poll, Hereford, and Angus breeds in crosses did not differ in weight at puberty, but the Red Poll and Angus breeds reached puberty at significantly younger ages than the Hereford breed in crosses. The Brown Swiss breed in crosses reached puberty at a significantly younger age than the three other breeds, and it was significantly heavier than the Hereford and Red Poll breeds in crosses when puberty was observed.

Postweaning Growth Traits Of Steers

Data on growth traits were analyzed on 584 steers. Effects of heterosis were significant for weight at 200, 312, and 424 days. Effects of heterosis on average daily gain decreased with increasing age; most of the heterosis observed on growth rate was expressed on preweaning average daily gain. Breed mean heterosis for growth traits of steers was highest in the Brown Swiss and Red Poll breeds and lowest in the Hereford breed.

Average reciprocal effect on weight in favor of steers with Red Poll and Brown Swiss dams was 78, 82, and 85 lb at 200, 312, and 424 days, respectively. The Brown Swiss and Red Poll breeds were superior in breed maternal effects to the Hereford and Angus breeds for weight at 200, 312, and 424 days.

The rank for breeds (high to low) in breed transmitted effects for 424-day weight was Brown Swiss, Angus, Hereford, and Red Poll.

The Brown Swiss breed in crosses was superior to the three other breeds for weight at 200, 312, and 424 days. The relative superiority of the Red Poll to Hereford and Angus in breed maternal effects and breed mean heterosis compensated for its relatively low level of breed transmitted effects and resulted in the Red Poll breed in crosses being equal to the Angus breed and significantly superior to the Hereford breed in crosses for weight at 424 days.

Carcass Traits Of Steers

Data were analyzed on 537 carcasses from steers on an age constant basis. Heterosis effects were significant for most of the carcass traits associated with growth rate, including slaughter weight, carcass weight, adjusted fat thickness, estimated retail product weight, estimated fat trim weight, and estimated bone weight. Differences in breed mean heterosis were not generally important.

Reciprocal differences were significant in favor of the Red Poll and Brown Swiss dams for most of the carcass traits associated with weight. Breed maternal effects were greatest in Red Poll and Brown Swiss breeds for carcass traits associated with weight.

The Brown Swiss breed ranked first and the Red Poll breed last in breed transmitted effects for carcass traits associated with weight. The Angus breed ranked first in breed transmitted effects for carcass quality grade and for other carcass traits associated with carcass fatness.

The Brown Swiss breed in crosses ranked significantly higher than crosses of the three other breeds for most carcass traits associated with weight. Also crosses of the Brown Swiss breed had a higher lean-to-fat ratio.

When carcass traits were adjusted to a constant carcass weight of 597 lb, heterosis effects, reciprocal differences, and breed maternal effects were not important. Thus the heterosis, reciprocal effects, and breed maternal effects were associated with growth rate.

Breed transmitted effects were important for traits associated with carcass composition after adjustments were made for the effects of weight. This observation shows that there are important breed differences on carcass traits independent of carcass weight.

[1]Keith E. Gregory is a research geneticist at MARC.

CHARACTERIZATION OF BREEDS REPRESENTING DIVERSE BIOLOGICAL TYPES: PREWEANING TRAITS

Keith E. Gregory,[1] Larry V. Cundiff, and Robert M. Koch

Introduction

The germ plasm base for beef cattle production in the United States has been broadened considerably during the last decade, primarily as a result of the development of appropriate quarantine facilities and procedures by the Canada Department of Agriculture that have provided for importing several new breeds of European origin. Also, the importation of new breeds, along with other factors, has stimulated interest in increased use for beef production of several breeds that have been available in North America for many years. The newly introduced breeds added to the breeds already available in the United States provide a wide range in performance characteristics in the cattle available for producing beef.

A high degree of uniformity in production systems at the terminal end of the beef cattle production cycle has evolved in the United States and Canada. A high percentage of young slaughter animals of both sexes have feeding periods of variable length on diets of high energy density as either castrate males or as nonpregnant females. This high offtake production system has been made possible largely as a result of new technologies in feed grain production, which have made it economically feasible to use large quantities of feed grains at the terminal end of the beef production cycle. Although the quantities and prices of feed grains may not continue at the levels required to favor their use for feeding cattle at the rate per animal that has characterized the beef cattle industry during the past quarter of a century, we believe that it will continue to be economically feasible to use some concentrate feed resources for "finishing" young slaughter animals. We believe that over the long term the basic concept or approach will be to use limited concentrate feed resources to most effectively supplement or to complement forage feed resources for all ruminant animal production.

While there is a high degree of uniformity in the feed environment provided at the terminal end of the beef production cycle, the opposite situation characterizes the feed environment of the reproducing animal. Considerable variation exists in both quantity and quality of feed resource base used by reproducing beef cattle and the climatic environment to which they are exposed, varying from desert ranges with less than 8 in of annual precipitation to improved pastures with annual precipitation levels of 50 in or more along with comparable differences in temperature, humidity, and air movement, which constitute the climatic environment.

The germ plasm resources now available for beef production in the United States vary considerably in performance level for specific traits. There is evidence of major differences in feed resource requirement associated with differences in performance level. Thus, the challenge is to synchronize germ plasm resources in regard to performance characteristics with the feed resources that are most economical to provide on a life cycle basis in terms of maximizing *output* per unit of *input* when viewed in the context of life cycle production systems.

From a breeding standpoint, there are three basic approaches that may be used to synchronize cattle germ plasm resources with *other production resources* and *market requirement of product*. These are (1) identify or select the breed that is the best "fit" or "match" to the production requirement (production resources and market requirement) and then select within this breed to increase "adaptability" to the production situation; (2) use systematic crossbreeding involving breeds that will complement each other most effectively to provide a more nearly optimum "blend" of characteristics desired; or (3) form a genetic pool by crossing breeds that provide a balance closest to the performance characteristics most desired for the production situation and then *inter se* mate the resulting progeny with a "minimum" rate of inbreeding and practice intrapopulation selection to form new breeds. The purpose of this paper is to characterize breeds representing diverse biological types that may be considered for use in these three approaches, rather than to give attention to the advantages and disadvantages or the "trade offs" involved in each of these approaches. However, it is appropriate to indicate that the two latter approaches make use of the phenomenon of heterosis or hybrid vigor, whereas the first approach does not.

Procedure

In 1969, MARC implemented a program to characterize a broad range of biological types of cattle as represented by breeds that differ widely in characteristics such as milk level, growth rate, carcass composition, and mature size. The primary objective was to characterize breeds representing diverse biological types for the full spectrum of traits relating to beef production. The germ plasm evaluation program at MARC has included three cycles of sire breeds that were bred by artificial insemination (AI) to Hereford and Angus dams. Hereford-Angus reciprocal crosses were repeated in each cycle as controls and to make possible the comparison of breeds included in different cycles. The first cycle involved breeding Hereford, Angus, Jersey, Limousin, South Devon, Simmental, and Charolais sires (20 to 35 sires per breed) by AI to Hereford and Angus dams (ranging from 2 to 7 years old at calving) to produce three calf crops in March and April of 1970, 1971, and 1972. In Cycle II, Hereford and Angus dams (ranging from 4 to 9 years old at calving) used in Cycle I were bred by AI to Hereford, Angus, Red Poll, Brown Swiss (predominantly European), Gelbvieh, Maine-Anjou, and Chianina sires to produce two calf crops in 1973 and 1974. Cycle III involved the same or comparable Hereford and Angus dams (ranging from 4 to 11 years old at calving) mated by AI to Hereford, Angus, Tarentaise, Pinzgauer, Sahiwal, and Brahman sires to produce two calf crops in 1975 and 1976. The same Hereford and Angus sires were used in all three cycles of the program to insure a more stable control population of Hereford-Angus reciprocal crosses as a basis for comparison of breeds included in different cycles of the program. In Cycles I and II, but not in Cycle III, Hereford and Angus sires were also mated to produce straightbred progeny of each of the two breeds.

The breeds that have been used in this program on which data are presented in this paper have been classified into six different biological types based on the criteria of (1) growth rate and mature size, (2) lean to fat ratio, (3) age at puberty, and (4) milk production. The groupings are reflected in Table 1 with the number of "X's" indicating relative differences between breed groups for each of the four criteria that provide the basis for classification.

The data presented in Table 2 were obtained by adding the average difference between specific breed groups and Hereford-Angus crosses within each cycle to the performance of Hereford-Angus crosses averaged over the three cycles.

Preweaning Traits

Results for birth and weaning traits from the three cycles are summarized in Table 2. Important differences were

[1]Keith E. Gregory is a research geneticist at MARC.

observed among sire breeds for gestation length, birth weight, calving difficulty, preweaning growth rate, and weaning weight. Calving difficulty ranged from a low of 2.9% in Hereford-Angus and Jersey crosses to a high of 20.4% in Maine-Anjou crosses. Brahman and Sahiwal crosses had significantly longer gestations than other breed groups. There was a positive association between average gestation length and birth weight of breed groups. Breeds siring the heaviest calves at birth tended to exhibit more calving difficulty than breeds siring lighter calves. However, at similar birth weights, breed groups such as Chianina and Brahman crosses had less calving difficulty than Maine-Anjou and Charolais crosses due perhaps to shape of calf or possibly other factors not now identified. The results presented in Table 2 for calving difficulty (%), calf crop weaned (%), and birth weight are from cows calving at 4 years of age or older. Results for these traits were pooled on this basis because cows were all 4 years old or older in Cycles II and III of the program. The association between calving difficulty and birth weight was greater in 2- and 3-year-old dams in Cycle I of the program.

Research at MARC has shown a fourfold increase in calf death loss when calving difficulty is experienced. Further, subsequent rebreeding performance has been reduced (85% vs 69% conception) in cows experiencing calving difficulty.

Table 1.—Breed crosses grouped in biological type on basis of 4 major criteria

Breed group		Growth rate and mature size	Lean to fat ratio	Age at puberty	Milk production	Number
Jersey-X	J	X	X	X	XXXXX	302
Hereford-Angus-X	HA	XX	XX	XXX	XX	962
Red Poll-X	R	XX	XX	XX	XXX	214
South Devon-X	SD	XXX	XXX	XX	XXX	232
Tarentaise-X	T	XXX	XXX	XX	XXX	202
Pinzgauer-X	P	XXX	XXX	XX	XXX	376
Sahiwal-X	Sa	XX	XXX	XXXXX	XXX	325
Brahman-X	Br	XXXX	XXX	XXXXX	XXX	349
Brown Swiss-X	BS	XXXX	XXXX	XX	XXXX	263
Gelbvieh-X	G	XXXX	XXXX	XX	XXXX	213
Simmental-X	Si	XXXXX	XXXX	XXX	XXXX	399
Maine-Anjou-X	MA	XXXXX	XXXX	XXX	XXX	222
Limousin-X	L	XXX	XXXXX	XXXX	X	371
Charolais-X	C	XXXXX	XXXXX	XXXX	X	382
Chianina-X	Ci	XXXXX	XXXXX	XXXX	X	238

Even though it has been the most important single factor contributing to calving difficulty, calf birth weight has accounted for less than 10% of the variation observed in calving difficulty in cows 4 years old and older.

Jersey crosses were significantly lighter than Hereford-Angus crosses at weaning. South Devon, Red Poll, and Sahiwal crosses had weaning weights similar to Hereford-Angus crosses. Limousin, Pinzgauer, and Tarentaise crosses were from 2 to 3% heavier than Hereford-Angus crosses at weaning. Weaning weights of Charolais, Simmental, Brown Swiss, Gelbvieh, Maine-Anjou, Chianina, and Brahman crosses exceeded Hereford-Angus crosses by 5% or more. For weight weaned per cow calving, only Brown Swiss and Brahman crosses significantly exceeded Hereford-Angus crosses.

Table 2.—Breed group means for birth and weaning traits of calves produced in Cycles I, II, and III

Breed group	Number	Gestation length (days)	Calving difficulty[1,2] (%)	Calf crop weaned[1,3] (%)	Birth weight[1] (lb)	ADG[4] (lb)	200-day weight (lb)	200-day weight ratio[5] (%)	Weight weaned per cow calving 200 days (lb)	Weight weaned per cow calving ratio[5] (%)
Jersey-X	302	282.9	2.9	92.3	68.6	1.70	406	94	375	90
Hereford-Angus-X	962	284.0	2.9	97.3	78.7	1.76	430	100	418	100
Red Poll-X	214	285.2	3.7	97.8	78.7	1.74	426	99	417	100
South Devon-X	232	286.7	11.9	92.9	83.1	1.74	430	100	399	95
Tarentaise-X	202	287.1	6.0	94.8	82.7	1.81	443	103	420	100
Pinzgauer-X	376	286.0	6.3	95.2	86.4	1.76	439	102	418	100
Sahiwal-X	325	294.0	6.2	94.3	83.8	1.74	432	100	407	97
Brahman-X	349	291.7	10.0	93.5	90.2	1.83	456	106	426	102
Brown Swiss-X	263	285.0	8.4	97.2	85.6	1.83	452	105	439	105
Gelbvieh-X	213	286.3	8.0	91.5	86.0	1.87	461	107	422	101
Simmental-X	399	287.3	14.9	89.1	88.9	1.83	452	105	403	96
Maine-Anjou-X	222	285.4	20.4	90.8	90.6	1.81	454	106	412	98
Limousin-X	371	289.2	9.4	91.7	85.8	1.76	437	102	401	96
Charolais-X	382	287.0	18.4	86.5	90.6	1.85	459	107	397	95
Chianina-X	238	287.5	11.8	91.1	89.3	1.83	456	106	415	99
Hereford dams[6]	2440	288.6	10.1	93.0	86.2	1.70	423		393	
Angus dams[6]	3129	285.4	6.5	94.2	80.9	1.87	454		428	

[1]Calving difficulty (%), calf crop weaned (%), and birth weight data are from cows calving at 4 years of age or older.
[2]Calving difficulty (%) is percentage of normal presentations requiring calf puller or C-section.
[3]Calf crop weaned is expressed as a percentage of all dams calving.
[4]ADG = average daily gain.
[5]Ratio relative to Hereford-Angus crosses.
[6]Includes straightbred progeny from Cycles I and II but does not include Hereford-Angus cross progeny from Cycle III in this and subsequent tables.

CHARACTERIZATION OF BREEDS REPRESENTING DIVERSE BIOLOGICAL TYPES: POSTWEANING GROWTH AND PUBERTY OF FEMALES

Keith E. Gregory,[1] Larry V. Cundiff, and Robert M. Koch

Introduction

Puberty traits in beef cattle are important criteria for evaluating the use of breeds for different beef production systems. Age at puberty is an important trait in beef cattle where females are bred to calve at 2 years of age, especially when a restricted breeding season is used. It is not only important that heifers reach puberty and conceive, but that they conceive early in the breeding season. Heifers that fail to reach puberty or that reach puberty and conceive late in the breeding season cause reduced production efficiency. Thus, from a breed selection standpoint, puberty is an important trait for identifying breed combinations most appropriate for different production situations.

Procedure

We bred heifers by artificial insemination (AI) for 42-days followed by 22 days of natural service mating in Cycles I and II and by natural service mating for the full breeding season of 63 days in Cycle III. Females were checked visually twice daily for estrus from an average age of about 250 days until the end of the breeding season when they averaged about 465 days. Weights were taken at 28-day intervals from weaning to the beginning of the breeding season, at the end of AI breeding season, and at approximately 550 days when heifers were palpated for preganancy.

From weaning in late October until they were placed on cool season pasture (about April 20), we fed heifers diets consisting of varying percentages of corn silage, alfalfa haylage, grass haylage, and a protein supplement when needed to meet nutritive requirements. The diet was the same for all breed groups and was considered adequate to develop females of most breed groups to breed as yearlings. Generally, we noted an improvement in the nutritive environment over the three cycles. Thus, the nutritive environment may have been above the optimum for some of the breed groups in Cycles II and III of the program.

Postweaning Growth Of Females

Results on postweaning growth from all three cycles are presented in Table 1. All females were retained to evaluate reproduction and maternal traits and were developed accordingly. Jersey, Red Poll, and Sahiwal crosses gained at a slower rate and had lower final weights than Hereford-Angus crosses. Limousin crosses exhibited about the same final weight as Hereford-Angus crosses. South Devon, Tarentaise, and Pinzgauer crosses had final weights of from 1 to 3% greater, whereas Brown Swiss, Brahman, Gelbvieh, Maine-Anjou, Chianina, Simmental, and Charolais crosses exhibited final weights of from 4 to 9% greater than Hereford-Angus crosses.

Puberty And Fertility Of F_1 Females

The females produced in the program were retained to evaluate reproduction and maternal performance traits. Difference among breed groups in age and weight at puberty and in percentage pregnant at 550 days are presented in Table 1.

Simmental, Maine-Anjou, South Devon, and Tarentaise crosses were similar to Hereford-Angus crosses in average age at puberty and intermediate to other breed groups. Gelbvieh, Brown Swiss, Pinzgauer, and Red Poll crosses reached puberty earlier than Hereford-Angus crosses, and Jersey crosses were the youngest of all breed groups when puberty was observed. Among *Bos taurus* breed groups, Limousin, Charolais, and Chianina crosses were oldest at puberty but were exceeded significantly by Sahi-

[1]Keith E. Gregory is a research genetist at MARC.

Table 1.—Breed group means of females produced in Cycles I, II, and III

Breed group	Number	200-day weight (lb)	200-day weight ratio[1]	400-day weight (lb)	400-day weight ratio[1]	550-day weight (lb)	550-day weight ratio[1]	550-day hip height[2] (in)	Weight at puberty (lb)	Weight at puberty ratio	Age at puberty (days)	Age at puberty ratio	Pregnant 550 days (%)
		FOR POSTWEANING GROWTH							FOR REPRODUCTION TRAITS				
Jersey-X	117	392	94	613	90	712	92	0	518	83	308	86	80.6
Hereford-Angus-X	322	419	100	681	100	772	100	46.1	622	100	357	100	87.2
Red Poll-X	95	410	98	655	96	750	97	46.4	580	93	337	94	84.8
South Devon-X	120	428	102	703	103	798	103	0	639	103	350	98	79.3
Tarentaise-X	85	432	103	701	103	796	103	47.6	622	100	349	98	96.2
Pinzgauer-X	114	437	104	703	103	798	103	48.0	611	98	334	94	99.2
Sahiwal-X	87	419	100	653	96	758	98	48.0	642	103	414	116	[3]103.2
Brahman-X	103	450	107	703	103	831	108	49.6	712	114	429	120	98.2
Brown Swiss-X	126	439	105	701	103	805	104	48.4	615	99	332	93	93.0
Gelbvieh-X	81	448	107	714	105	822	106	48.4	626	101	326	91	93.2
Simmental-X	157	441	105	723	106	825	107	0	666	107	358	100	80.4
Maine-Anjou-X	89	441	105	734	108	838	108	48.4	672	108	357	100	94.2
Limousin-X	161	423	101	692	102	770	100	0	679	109	384	108	76.2
Charolais-X	132	448	107	723	106	814	105	0	703	113	384	108	74.8
Chianina-X	92	443	106	714	105	833	108	50.8	699	112	384	108	85.6
Hereford dams	997	415	0	675	0	787	0	48.4	642	0	379	0	90.4
Angus dams	1103	441	0	695	0	787	0	48.0	635	0	351	0	87.7

[1]Ratio relative to Hereford-Angus crosses.
[2]550-day hip height data were not collected on the Cycle I females.
[3]In Cycle III, only 82.0 percent of Angus-Hereford crosses were pregnant at 550 days whereas 98 percent of the Sahiwal crosses were pregnant at 550 days.

Table 2.—Postweaning growth rate, puberty, and conception rate of Hereford-Angus cross females in each of the three cycles

Cycle	Number of animals	200-day weight (lb)	ADG 220 to 400 days (lb)	400-day weight (lb)	550-day weight (lb)	Age at puberty (days)	Weight at puberty (lb)	Pregnant 550 days (%)
I	132	415	1.08	631	717	371	586	93.0
II	89	404	1.30	664	765	374	626	86.6
III	101	437	1.55	747	831	326	653	82.0
Average		419	1.31	681	772	357	622	87.2

wal and Brahman crosses. Larger, later maturing breeds are expected to be older at puberty. Considering their mature size, South Devon, Simmental, Maine-Anjou, Pinzgauer, Brown Swiss, and Gelbvieh crosses reached puberty at relatively young ages. Breeds that have been selected for milk production appear to reach puberty earlier than breeds of similar growth rate and mature size that have not been selected for milk production. The negative relationship between milk production and age at puberty may be as great as the positive relationship between mature size and age at puberty. Also, it would appear that the Sahiwal and Brahman breeds may have been subjected to selection pressures, which set them apart from the *Bos taurus* breeds in regard to age at which they exhibit puberty.

Breed groups varied in percentage pregnant at 550 days (Table 1). As shown by the results presented in Table 2 for the Hereford-Angus crosses for each of the three cycles, we noted a general improvement in the nutritive environment provided during the postweaning period. Rate of gain increased in each cycle, and age at puberty was about the same for the first two cycles but decreased significantly for the third cycle. Weight at 200 days was least in Cycle II and greatest in Cycle III. Weight at puberty increased in each cycle. Conception rate for Hereford-Angus crosses was 93.0% for Cycle I, 86.6% for Cycle II, and 82.0% for Cycle III (Table 2). The conception rate for Hereford-Angus crosses in Cycle I was higher than for the Limousin and Charolais crosses, which reached puberty 27 days later (Table 1). However, in Cycle III the conception rate of the Brahman and Sahiwal crosses exceeded Hereford-Angus crosses by 11% and 16%, respectively, even though age at puberty was 72 days greater in the Brahman crosses and 57 days greater in Sahiwal crosses than in Hereford-Angus crosses. The *actual* age at puberty was 398 days in the Limousin and Charolais crosses (Cycle I), whereas, the *actual* age at puberty was 398 days for the Brahman crosses and 383 days for the Sahiwal crosses (Cycle III).

The nutritive environment provided in Cycle I may have been closer to the optium for maximizing conception rate in yearling heifers of the Hereford-Angus crosses relative to the breed groups that reached puberty later, whereas, the reverse seems to have been the case in Cycle III of the program. These results suggest that a plane of nutrition for developing heifers to breed as yearlings that is appreciably above the level required for the heifers to reach puberty may actually result in a reduced conception rate.

CHARACTERIZATION OF BREEDS REPRESENTING DIVERSE BIOLOGICAL TYPES: POSTWEANING GROWTH AND FEED EFFICIENCY

Larry V. Cundiff,[1] Robert M. Koch, and Keith E. Gregory

Introduction

On a life-cycle basis, about 30% of the energy requirements for beef production are consumed by steers and heifers during the period from weaning to slaughter. About 45 to 55% of the total feed costs are incurred in the postweaning period, depending on the cost of feed resources for the cow herd relative to those for the feedlot. We find it is important, therefore, to characterize breeds of cattle for rate and efficiency of postweaning gain.

Procedure

Steers were weaned in late October and allowed a conditioning period of about 28 days before feeding trials were initiated in mid-November of each year when the steers were about 8 months of age. Steers were fed free choice diets consisting of corn silage-concentrate (concentrate contained varying amounts of ground corn, ground grain sorghum, and ground wheat) and supplement (primarily soybean meal) varying in energy density from 1.2 Mcal metabolizable energy (ME/lb) dry matter early in the feeding period to about 1.35 Mcal ME/lb dry matter late in the feeding period.

Steers were allotted to pens by sire breed groups except that Hereford-Angus reciprocal crosses were penned together. Breed groups were randomly divided into two pens each year to provide for statistical analyses of postweaning feed efficiency. Steers were slaughtered in three to five groups each year with an average interval of 70 days between the first and last kill. Time on feed required to reach end points of a small degree of marbling or 18.9% fat trim was estimated from increases in marbling or fat trim associated with increased time on feed. Steers were generally weighed at 28-day intervals. Quadratic regression of pen mean weights and cumulative ME on days fed were used to estimate gain, ME consumption, and efficiency (Mcal ME/lb gain) in alternative intervals.

Efficiency of live weight gain was evaluated for four different intervals: time constant (0 to 238 days on feed), weight constant (545 to 1,035 lb), grade-constant (0 days on feed to a small degree of marbling), and fat-trim constant (0 days on feed to 18.9% fat trim). The level of marbling selected as an end point was small because this is the level of marbling required for cattle of these ages to achieve a quality grade of USDA Choice. The 18.9% fat trim level was the average fat trim for breed groups at 0.5 in fat thickness at the 12th rib.

Results

Results presented in Table 1 for postweaning growth and feed efficiency to time, weight, grade, and fat trim end points are organized on the basis of biological type. Important differences were observed among breed groups in postweaning growth rate and final weight.

In the postweaning period, Jersey, Red Poll, and Sahiwal cross steers gained more slowly and had lower final weights than Hereford-Angus cross steers. Brahman, South Devon, Tarentaise, and Pinzgauer cross steers had final weights 1 to 3% greater than those of Hereford-Angus cross steers. Brown Swiss, Gelbvieh, Simmental, Maine-Anjou, Charolais, and Chianina cross steers were 4 to 9% heavier than Hereford-Angus cross steers in final weight.

Feed efficiency for different intervals of evaluation is summarized in Table 1. The range between breed groups was greatest in the weight-constant interval. Brown Swiss, Gelbvieh, Simmental, Maine-Anjou, Charolais, and Chianina crosses were most efficient; Hereford-Angus, South Devon, Tarentaise, Pinzgauer, Limousin, and Brahman crosses were intermediate; and Jersey, Red Poll, and Sahiwal crosses were least efficient in conversion of ME to live-weight gain from 545 to 1,036 lb. The correlation between breed-group means for 452-day weight and feed efficiency in the weight-

[1]Larry V. Cundiff is a research leader (Breeding and Genetics) at MARC.

Table 1.—Breed group means for postweaning growth and feed efficiency to time, weight, grade, and fat-trim end points

					Feed efficiency (Mcal ME/lb gain)			
Breed group	Number	Post-weaning ADG (lb)	452-day weight (lb)	452-day weight ratio[1]	Time 0 to 238 days	Weight 545 to 1,036 lb	USDA Choice 0 days to small marbling	Fat trim 0 days to 18.9% fat trim
Jersey-X	132	2.23	981	94	10.90	11.76	11.06	10.43
Hereford-Angus-X	508	2.40	1046	100	10.49	10.67	10.54	10.07
Red Poll-X	111	2.20	995	95	11.36	11.49	11.54	11.34
South Devon-X	94	2.58	1082	103	10.35	10.40	10.72	10.29
Tarentaise-X	103	2.38	1054	101	10.75	10.97	11.39	11.11
Pinzgauer-X	176	2.45	1058	101	10.44	10.60	10.77	10.84
Sahiwal-X	154	2.20	999	96	11.04	11.80	11.55	10.98
Brahman-X	153	2.40	1068	102	10.83	11.00	11.81	10.98
Brown Swiss-X	154	2.47	1087	104	10.36	9.67	10.84	11.20
Gelbvieh-X	111	2.56	1115	107	10.17	9.45	10.92	11.11
Simmental-X	176	2.69	1141	109	10.36	9.95	11.20	11.47
Maine-Anjou-X	109	2.65	1133	108	10.22	9.35	11.01	11.84
Limousin-X	173	2.32	1035	99	10.15	10.25	11.74	11.70
Charolais-X	176	2.67	1143	109	10.02	9.46	10.94	11.61
Chianina-X	119	2.49	1099	105	10.39	9.86	12.13	13.29

[1]Ratio relative to Hereford-Angus crosses.

constant interval was -0.91, indicating that larger breed groups required significantly less Mcal of ME/lb of gain than smaller breed groups to grow from 545 to 1,036 lb. Breed groups with the most rapid growth rates required less feed per unit of gain than slower-gaining groups in the weight-constant interval primarily because fewer days of maintenance were required in the weight-constant interval.

The ranking and relative differences of breed groups for feed efficiency in the time-constant interval (0 to 238 days postweaning) were similar to that for the weight-constant interval, but the range and differences between breed groups were smaller. The larger, faster-gaining breed groups that were heaviest at weaning maintained more weight throughout the time-constant interval. Even with heavier weights maintained, the faster-gaining breed groups were more efficient in the time-constant interval. The correlation between breed-group means for 452-day weight and feed efficiency in the time-constant interval was -0.78.

Feed efficiency from weaning (except for adjustment period of about 28 days) to a grade-constant end of USDA Choice (0 days to small amount of marbling) or to a fat trim-constant end point of 18.9% is also presented in Table 1. The ranking of breed groups for feed efficiency to a USDA Choice grade end point was similar to that to a fat-trim end point (correlation of breed group means was 0.66). There is considerable difference in the ranking of breed-group means for feed efficiency to a grade- or a fat-constant end point compared to ranking for feed efficiency to a time- or a weight-constant end point.

To a grade end point of USDA Choice, Hereford-Angus crosses were significantly more efficient than Charolais, Brown Swiss, Gelbvieh, Chianina, Tarentaise, Brahman, and Sahiwal crosses. The correlation of breed-group means for 452-day weight and feed efficiency to a grade end point was only -0.14, indicating no significant association between size and feed efficiency (Mcal of ME/lb of gain) to a grade end point. The correlation of breed-group means for number of days on feed required to reach a small degree of marbling and feed efficiency to a grade end point was 0.62. Breed groups reaching a small degree of marbling in the fewest days tended to be more efficient, primarily because fewer days of maintenance were required. Evaluation to a grade-constant end point assumes that feeding to higher levels of fatness is justified in terms of improving the eating quality of beef. Taste-panel evaluations of flavor, juiciness, and tenderness indicated that this assumption was not justified.

To a fat-trim end point of 18.9%, Hereford-Angus crosses were significantly more efficient than Limousin, Charolais, Simmental, Red Poll, Brown Swiss, Gelbvieh, Maine-Anjou, Chianina, Pinzgauer, Tarentaise, Brahman, and Sahiwal crosses. The correlation among breed group means between 452-day weight and feed efficiency (Mcal of ME/lb of gain) to a fat-trim end point was 0.40, indicating that breeds of larger size tended to be less efficient than breeds of smaller size to the fat-trim end point. The correlation of breed group means for number of days on feed required to reach 19% fat-trim and feed efficiency to a fat-trim end point was 0.92. Breed groups reaching the 18.9% fat-trim end point in the fewest days tended to be more efficient, primarily because fewer days of maintenance were required.

CHARACTERIZATION OF BREEDS REPRESENTING DIVERSE BIOLOGICAL TYPES: CARCASS AND MEAT TRAITS OF STEERS

Robert M. Koch,[1] Larry V. Cundiff, Keith E. Gregory and M. E. Dikeman

Introduction

Carcass characteristics, including composition and palatability of meat from different breeds or breed crosses, are important in determining the potential value of alternative germ plasm resources.

Procedure

The sire breeds evaluated represented biological types that differed widely in mature size and rate of fattening. Hereford-Angus reciprocal crosses were repeated in each of three breeding cycles as controls and to make possible the comparison of breeds included in different cycles. The first cycle involved breeding Hereford, Angus, Jersey, Limousin, South Devon, Simmental, and Charolais sires by artifical insemination (AI) to Hereford and Angus dams to produce three calf crops in March and April of 1970, 1971, and 1972. In Cycle II, Hereford and Angus dams used in Cycle I were bred by AI to Hereford, Angus, Red Poll, Brown Swiss (predominately European), Gelbveih, Maine-Anjou, and Chianina sires to produce two calf crops in 1973 and 1974. Cycle III involved the same or comparable Hereford and Angus dams mated by AI to Hereford, Angus, Tarentaise, Pinzgauer, Sahiwal, and Braham sires to produce two calf crops in 1975 and 1976.

Each year steers were slaughtered at each of three to five slaughter dates spaced about 1 month apart. Slaughter at several dates provided a range in age, weight, and degree of fatness for each of the breed groups. This design permitted us to estimate values that would be obtained if animals in a breed group had been fed fewer or more days until the breed group average reached a given end point with regard to (1) age, (2) carcass weight, or (3) fat trim percentage.

Slaughter was carried out at a commercial packing plant. After a 24-hr chill, carcasses were evaluated for maturity, marbling, color, texture, firmness, and USDA quality and yield grades. The right side was trucked to Kansas State University were it was processed to obtain detailed cutout information and taste panel evaluation under the direction of Dr. Michael E. Dikeman.

The round, rib, loin, and chuck were separated into wholesale cuts and processed into closely trimmed, boneless retail cuts, except for a small amount of bone left in the short loin and rib roasts. Fat was trimmed to no more than 0.3 in on any surface. Lean from the flank, plate, brisket, and shank were added to the lean trim from the four major cuts. Chemical analysis of the lean trim in each carcass was used to adjust total lean trim to a 25% ether extract basis. The sum of roasts and steak meat plus adjusted lean trim was called retail product. Steaks at the 10th and 11th ribs from four representative carcasses of each breed group at each slaughter date were frozen and later used for a Warner-Bratzler shear force determination for tenderness and a taste panel evaluation of tenderness, flavor, and juiciness.

Results

Breed group means for carcass traits of steers from Cycles I, II, and III adjusted to a constant age of 458 days and to a constant fat trim of 19% are presented in Table 1. Equal age comparisons provide a measure of differential growth rate and are related to mature size. Results presented in Table 1 reflect a large amount of genetic variation in growth rate. At equal ages, breed groups differed in carcass weight by as much as 19% and also varied greatly in composition of carcasses. Carcass weight varied more widely (Chianina crosses were 69% heavier than Jersey crosses) between breed groups at equal fat trim than at equal age, with the maximum difference in retail product percentage reduced to 1.7 at equal fat trim (Limousin vs Jersey crosses). Rapid

[1]Robert M.Koch is a University of Nebraska–Lincoln research geneticist stationed at MARC.

Table 1.—Breed group means for carcass traits—Cycles I, II, and III

Breed group	Number	Shrunk live weight (lb)	Carcass weight (lb)	Fat thickness (in)	Marbling score[1]	Retail product (%)	Fat trim (%)	Bone (%)	Kidney fat (%)	Live weight (lb)	Carcass weight (lb)	Fat thickness (in)	Marbling score[1]	Retail product (%)	Bone (%)	Kidney fat (%)
		ADJUSTED TO A CONSTANT AGE OF 458 DAYS								ADJUSTED TO 19 PERCENT FAT TRIM						
Jersey-X	134	958	593	0.46	13.3	65.5	22.1	12.4	6.2	879	537	0.37	11.8	68.0	13.0	5.6
Hereford-Angus-X	472	1008	637	.64	11.3	66.3	21.7	12.0	3.9	935	584	.53	10.2	68.4	12.6	3.6
Red Poll-X	106	979	618	.49	11.2	66.6	21.0	12.4	5.1	928	581	.43	10.4	68.2	12.8	4.8
South Devon-X	94	1031	655	.48	11.3	67.7	20.0	12.3	4.7	1010	639	.46	10.9	68.5	12.5	4.5
Tarentaise-X	102	1010	638	.44	10.1	69.8	17.7	12.5	4.9	1016	645	.44	10.4	68.6	12.4	5.1
Pinzgauer-X	130	1017	629	.46	10.8	69.4	17.5	13.1	4.4	1028	640	.46	11.2	68.0	13.0	4.6
Sahiwal-X	141	962	611	.54	9.7	69.1	18.4	12.4	3.9	951	606	.52	9.7	68.5	12.5	4.0
Brahman-X	128	1033	663	.56	9.3	69.4	18.0	12.6	4.1	1032	665	.55	9.5	68.4	12.6	4.3
Brown Swiss-X	120	1076	677	.39	10.4	69.1	17.6	13.3	4.0	1144	723	.46	11.2	68.1	12.9	4.1
Gelbvieh-X	108	1090	687	.37	9.7	69.8	17.4	12.8	4.5	1169	741	.45	10.6	68.7	12.3	4.7
Simmental-X	175	1079	673	.39	9.9	71.0	15.6	13.4	4.3	1251	791	.55	11.9	68.6	12.4	4.8
Maine-Anjou-X	109	1103	704	.37	10.2	70.2	16.5	13.3	4.1	1223	787	.48	11.5	68.4	12.6	4.4
Limousin-X	177	1021	652	.41	8.9	72.4	15.1	12.5	4.3	1214	787	.60	11.0	69.7	11.3	4.9
Charolais-X	177	1093	691	.38	10.3	71.8	15.2	13.0	4.2	1291	828	.55	12.6	69.1	11.9	4.8
Chianina-X	112	1077	690	.32	8.5	73.0	13.0	14.0	3.8	1390	910	.57	11.7	68.8	12.2	4.6
Hereford dams[2]	1044	1025	643	.43	9.8	69.7	17.3	13.0	4.1	1082	683	.50	10.6	68.4	12.6	4.4
Angus dams[2]	1353	1024	651	.51	11.1	68.3	19.4	12.3	4.5	1015	645	.50	10.9	68.6	12.4	4.5

[1]Marbling scores: traces = 4, 5, 6; slight = 7, 8, 9; small = 10, 11, 12; modest = 13, 14, 15.
[2]Includes straightbred progeny from Cycles I and II but does not include Hereford-Angus cross progeny from Cycle III.

Table 2.—Percentage of carcass in whole cuts and percentage of total retail product, fat trim, or bone in each cut at a constant carcass weight

Item	Round	Chuck	Loin and rib	Minor cuts	Kidney knob	Round	Chuck	Loin and rib	Minor cuts	Kidney knob
			Whole cut					Fat trim		
Jersey-X	20.99	26.18	21.43	25.03	6.33	7.59	11.76	14.91	39.31	26.43
Hereford-Angus-X	22.72	26.35	21.90	25.08	3.94	9.64	12.95	18.33	41.12	17.96
Red Poll-X	22.27	26.49	21.58	24.33	5.34	7.46	12.57	15.72	39.49	24.76
South Devon-X	23.17	26.10	21.87	24.23	4.58	8.96	11.43	16.36	39.84	23.41
Tarentaise-X	22.73	26.36	21.99	23.94	4.97	6.77	10.83	15.92	39.92	26.56
Pinzgauer-X	22.92	26.56	21.88	24.16	4.47	7.36	11.80	16.16	40.76	23.92
Sahiwal-X	22.98	25.68	22.28	24.67	4.37	8.01	10.63	17.11	43.37	20.88
Brahman-X	23.68	26.25	21.72	24.22	4.12	7.94	8.67	16.26	43.93	23.20
Brown Swiss-X	23.99	26.94	21.87	23.32	3.88	7.74	10.14	16.12	41.77	24.23
Gelbvieh-X	23.27	26.89	21.76	23.76	4.32	6.19	8.48	15.37	42.84	27.12
Simmental-X	24.19	26.72	21.50	23.40	4.18	7.09	10.49	14.55	41.05	26.82
Maine-Anjou-X	24.32	26.91	21.60	23.39	3.78	5.05	6.53	15.18	44.73	28.51
Limousin-X	24.19	26.47	22.05	23.15	4.18	7.02	8.84	16.18	40.82	27.14
Charolais-X	24.76	26.39	21.72	23.21	3.93	8.01	9.66	14.55	40.73	27.05
Chianina-X	25.00	27.43	21.80	22.25	3.52	3.23	4.80	14.88	45.04	32.05
Average	23.41	26.52	21.80	23.88	4.39	7.20	9.97	15.84	41.65	25.34
			Retail product					Bone		
Jersey-X	24.56	30.72	24.74	19.98	---	28.67	30.64	17.07	23.63	----
Hereford-Angus-X	25.80	30.02	24.05	20.14	---	29.76	30.72	16.52	23.01	----
Red Poll-X	25.81	30.23	24.35	19.62	---	29.49	31.00	16.87	22.65	----
South Devon-X	25.84	29.46	24.33	20.45	---	30.07	30.19	16.62	23.13	----
Tarentaise-X	25.89	29.82	24.49	19.81	---	29.46	30.51	17.11	22.93	----
Pinzgauer-X	25.88	29.85	24.43	19.85	---	29.91	30.41	16.43	23.26	----
Sahiwal-X	26.40	29.65	24.71	19.25	---	30.21	29.82	17.63	22.35	----
Brahman-X	26.54	30.02	24.02	19.43	---	30.17	30.11	16.53	23.20	----
Brown Swiss-X	26.54	30.12	24.39	18.96	---	30.81	30.75	15.88	22.57	----
Gelbvieh-X	26.02	30.39	24.25	19.35	---	30.03	30.87	16.41	22.70	----
Simmental-X	26.56	29.61	23.99	19.85	---	30.62	30.19	16.29	22.91	----
Maine-Anjou-X	26.79	30.06	23.93	19.23	---	30.84	30.46	16.01	22.70	----
Limousin-X	26.66	29.50	24.21	19.64	---	30.11	30.49	16.54	22.87	----
Charolais-X	26.81	29.02	24.13	20.04	---	30.98	30.22	16.07	22.74	----
Chianina-X	27.27	30.37	24.01	18.36	---	31.17	30.26	16.28	22.30	----
Average	26.22	29.92	24.27	19.60	---	30.15	30.44	16.55	22.86	----

growing breed groups had less fat trim and more retail product and bone, which required these breed groups to be carried to heavier weights to attain equal fat trim percentages.

Percentage of the carcass in wholesale cuts, round, chuck, loin and rib, minor cuts, and kidney knob, are shown in Table 2. Minor cuts include the flank, plate, brisket, and foreshank. There was some variation among breed groups, particularly in the round, minor cuts, and kidney knob. The cause of the whole cut variation is best examined by considering the relative amount of the total retail product, fat trim, or bone in each cut, which is also shown in Table 2. The largest differences among breed groups in distribution of retail product were in the round. There was a tendency for the later maturing breed groups to have a larger percentage of their muscle in the round than the earlier maturing groups. Chianina crosses had the highest (27.27%) and Jersey crosses the lowest (24.56%) amount of their retail product in the round. However, the similarities of breed groups in distribution of retail product among cuts were more striking than the differences. The amounts of retail product in the highest priced cuts, the loin and rib, were remarkably similar. No breed group deviated more than 0.5% from the average, and most were within 0.25% of the average. Jersey crosses had the highest percentage of loin and rib (24.7%). Distribution of the fat trim by cuts did vary significantly among breed groups. Kidney and pelvic fat showed the greatest variation. There was a tendency for the earlier maturing breed groups to have less and the later maturing groups to have more of their fat trim in the kidney and pelvic region. Hereford-Angus crosses had the lowest (17.96%) and Chianina crosses the highest (32.05%) relative percentage of fat trim in the kidney knob. Differences among breed groups in distribution of bone were not large and were similar to differences in distribution of retail product.

Marbling score is the primary determinant of carcass quality grade. As indicated by Table 3, at equal age, breed groups differed significantly in average marbling scores and in percentage of carcasses that had adequate marbling to grade USDA Choice or better. Breed groups that had the highest marbling scores had higher fat trim percentages (Tables 1 and 3). These results show that the genetic relationship between marbling score and fat trim is high. Thus, there is only limited opportunity to increase carcass quality grade through breeding without increasing total fat.

Taste panel evaluation of rib samples from about 1,230 animals is summarized in Table 3. One of the most significant findings in the carcass and meat trait eval-

Table 3.—Breed group means for factors identified with meat quality—Cycles I, II, and III

Breed crosses	Marbling[1]	Percent choice	Warner-Bratzler shear (lb)	Flavor[1]	Juiciness[1]	Tenderness[1]
Chianina-X	8.3	24	7.9	7.3	7.2	6.9
Limousin-X	9.0	37	7.7	7.4	7.3	6.9
Brahman-X	9.3	40	8.4	7.2	6.9	6.5
Gelbvieh-X	9.6	43	7.8	7.4	7.2	6.9
Sahiwal-X	9.7	44	9.1	7.1	7.0	5.8
Simmental-X	9.9	60	7.8	7.3	7.3	6.8
Maine-Anjou-X	10.1	54	7.5	7.3	7.2	7.1
Tarentaise-X	10.2	60	8.1	7.3	7.0	6.7
Charolais-X	10.3	63	7.2	7.4	7.3	7.3
Brown Swiss-X	10.4	61	7.7	7.4	7.2	7.2
Pinzgauer-X	10.8	60	7.4	7.4	7.2	7.1
South Devon-X	11.3	76	6.8	7.3	7.4	7.4
Hereford-Angus-X	11.3	76	7.3	7.3	7.3	7.3
Red Poll-X	11.5	68	7.4	7.4	7.1	7.3
Jersey-X	13.2	85	6.8	7.5	7.5	7.4

[1]Marbling: 5 = traces, 8 = slight, 11 = small, 14 = modest, 17 = moderate. Taste panel scores. 2 = undesirable, 5 = acceptable, 7 = moderately desirable, 9 = extremely desirable.

uations was the generally high level of acceptance of meat from all breed groups that came from the same production system but with major differences in size of carcass, fatness, and marbling. Cooking preparation was carefully controlled. Taste panel scores did tend to increase as marbling increased when comparisons were at the same age, but the change was *slight*. While still in the acceptable to moderately desirable range, tenderness scores of the cooked meat were less for the Sahiwal and Brahman crosses than for the breed crosses of European origin. Results from MARC show that marbling accounts for only about 8% of the variation in meat palatability in young cattle fed and managed alike and slaughtered at 14 to 16 months of age.

The rather high degree of acceptance by taste panel evaluation and the low relationship of taste panel scores with marbling score suggest that the production system and cooking preparation will likely be the most effective means of improving eating satisfaction rather than through breeding.

GENETIC VARIATION AMONG AND WITHIN HERDS OF ANGUS AND HEREFORD CATTLE

Larry V. Cundiff[1] and Keith E. Gregory

Introduction

Historically, beef cattle record of performance programs have by necessity expressed variation as deviations or ratios from herd means because differences between herds are believed to be large primarily because of environment. To the extent differences between herds are genetic, this procedure underestimates or overestimates breeding values of individuals relative to breed average depending on whether they are produced in herds of above or below average genetic merit for a breed. We conducted this study in cooperation with the American Angus Association and the American Polled Hereford Association, and designed it to separate and evaluate the relative importance of between-herd and within-herd sources of genetic variation for birth, growth and carcass characteristics.

Procedure

Birth and livability data on 995 calves, weaning data on 915 calves, and postweaning growth and carcass data on 817 calves produced in two calf crops were studied. Calves were sired by 51 bulls from 18 Angus herds (2 to 3 sires/herd) and 44 bulls from 18 Polled Hereford herds (2 to 4 sires/herd) through artificial insemination (AI) matings. Semen was provided by the American Angus Association and the American Polled Hereford Association for their respective breeds. The cows were straightbred Angus and Hereford calving as 2- and 3-year-olds mated to produce straightbred and reciprocal cross calves.

The calving season was from March 4 to May 4 in each year. Calves were creep fed whole oats from July to weaning in late October. After weaning, steer and heifer calves were fed a ration comprised of corn silage, steam flaked corn, dehydrated alfalfa pellets, and a 40% crude protein supplement ranging in energy density from 1.4 Mcal ME/lb dry matter early in the feeding period to 1.5 Mcal ME/lb later in the feeding period. They were fed 229 days in the first year and 299 days in the second year. Carcass data were obtained in a commercial packing plant about 24 hr after slaughter.

Results

Results indicated that both within and between herd sources of genetic variation significantly influenced growth and carcass traits. Herds were a significant source of genetic variation for birth weight, 200-day weaning weight, postweaning average daily gain (ADG), 452-day weight, final grade, carcass conformation, and marbling. Sires within herd were a significant source of genetic variation for postweaning ADG, 452-day weight, final carcass grade, carcass conformation, marbling, fat thickness, rib-eye area, and estimated cutability.

Variance components for herds (H), sires within herd (S), and progeny within sires and herd (W) expressed as a percentage of total variance (H + S + W) are shown in Table 1. The correlation among breeding value for herd mates (R) and heritability (h^2_t and h^2_w) are also presented in Table 1.

Estimates of the correlation between breeding value of sires produced in the same herd (R) ranged from 0.37 to 0.69 for growth traits and from -0.10 to 0.34 for carcass traits. R is expected to be greater than zero only to the extent that genetic diversity exists between herds as a result of (1) extra pedigree likeness among individuals produced in the same herd relative to those in other herds, (2) differential selection pressure and response between herds, (3) random genetic differences between herds that have accrued by chance, or (4) sampling of bulls in this study. The average pedigree relationship of bulls sampled in this experiment was 0.11 in both breeds, and only one-fourth of this, or about 0.03, is to be reflected in coefficients of R derived for each trait in this study. Thus, the relatively high coefficients found for R indicate that differential selection pressure and response have resulted in substantial genetic diversity between herds of the Angus and Polled Hereford breeds, especially for growth traits.

The heritability estimates (h^2_t and h^2_w) shown in Table 1 pertain to different populations of inference. Tabled figures are shown in percentage. The first estimate (h^2_t) is expected to apply when sires sampled from a number of herds are progeny tested in the environment of a single herd, or when progeny performance of individual sires can be compared against that of reference sires in multiherd national sire evaluation programs. The second estimate (h^2_w) applies to closed herds. In herds outcrossing to sires from many herds, heritability would fall between h^2_t and h^2_w.

Estimates of h^2_t were larger than those for h^2_w in proportion to the influence of herd effects. Extra genetic variation arising from between herd sources increases the effectiveness of sequential selection based first on individual performance of bulls selected within herds and then between herds on the basis of progeny performance relative to closed herd selection or outcrossing with selection based on variation within herds. Rate of genetic change in a breed is accelerated when progeny test scores of the reference sires are used to identify outstanding sires for wide spread use through AI not only because of increased selection intensity but also because heri-

Table 1.—Percentage of variance from herds (H), sires/herds (S), and progeny/sires (W); correlation between sires from the same herd (R); and heritability within breed (h^2_t) and within herd (h^2_w)

Trait	Percentage of total (H + S + W)[1] H (%)	S (%)	W (%)	R (%)	h^2_t (%)	h^2_w (%)
			(%)			
Calving difficulty	1.8	−1.7	99.9	. . .	0	-7
Birth wt	3.9	2.4	93.8	62	22	10
Live-birth	1.0	1.4	97.6	58	10	4
Live-72 hr	.9	1.5	97.7	63	9	4
Live-weaning	3.3	.2	96.5	6	14	13
ADG, birth-wt	1.5	2.5	96.1	37	15	10
200 day wt	2.6	1.2	96.2	69	14	5
ADG wt-fin	5.6	8.0	86.4	41	46	34
452-day wt	5.2	6.5	88.3	44	40	27
Final grade	4.2	9.7	86.0	30	50	41
Conf. grade	4.4	8.2	87.5	34	44	34
Marbling	4.0	10.6	85.4	28	52	44
Fat thickness	−.7	7.7	93.0	10	28	31
Longissimus area	.5	8.2	91.3	6	24	33
Estimated cutability	.4	5.8	93.9	6	24	23

[1] = 1/4 the genetic variance between herds = [1/4 (RV_G)], S = 1/4 the genetic variance within herds = [1/4 (1-R) V_G], W = 3/4 the genetic variance within herds plus environmental variance within herds = [3/4 (1-R) V_G + (1-C) V_E], R = the correlation among breeding values of herd mates = H / (H + S), h^2_t = 4 (H + S) / 4(H + S + W), and h^2_w = 4S/(S + W).

Continued at bottom of next page.

[1]Larry V. Cundiff is a research leader (Breeding and Genetics) at MARC.

CONCEPTION AND EMBRYONIC DEVELOPMENT IN THE BEEF FEMALE

Ralph R. Maurer,[1] Sherrill E. Echternkamp, and William F. Pope

Introduction

Reproduction is an important economic trait in beef cattle production. The average percent calf crop for the United States has been estimated between 80 to 85%. Approximately 60% of the reduction in calf crop can be attributed to fertilization failure and embryonic death. We conducted several studies to determine at what stage of the reproductive cycle losses were incurred in normal reproducing cows and heifers and in cows and heifers that failed to reproduce. In addition, we measured hormone levels in normal range cows and heifers and used techniques like embryo transfer and culture to study the development of the embryo.

Procedure

Embryonic Development in Cows and Heifers. One hundred two, two- or three-way crossbred heifers, 18 to 24 months old, and 57 Black Angus, Limousin x Black Angus, or Limousin x Hereford crossbred cows, 3 to 12 years old, were mated to Black Angus or Red Poll bulls. The mated females were slaughtered on days 2 to 8 or 14 to 16 of gestation (day 0 = day of estrus) and their reproductive tract flushed with phosphate buffered saline to recover an oocyte or embryo. The results are presented in Table 1. In cows, a 100% recovery and fertilization rate was found while in heifers, 91% of the ova or embryos were recovered and 15% were classified as unfertilized. After 8 days of gestation, embryonic death was occurring or had occurred in 15% of embryos from heifers and 17% of embryos from cows. At days 14 to 16 of gestation, the increase in the percentage of nonrecoverable embryos in both cows and heifers can be attributed to fertilization failure and embryonic death. In the heifers, most of embryonic death had occurred by day 8 of gestation while in cows, 63% of the embryonic death had occurred or was occurring by day 8 and continued until day 16 of gestation. Cows and heifers had the same percentage of normal developing embryos at days 14 to 16, but the losses incurred were by fertilization failure and embryonic death in heifers but only by embryonic death in cows. Biologically, the increase in fertilization failure in heifers would be reasonable since heifers that fail to reproduce are culled after two exposures of 45 days to bulls. Therefore, cows would be expected to have a higher fertilization rate than heifers.

Table 1.—Recovery and fertilization rates and percentage of normally developing embryos at 2 different times during gestation

Days after mating	Females: Type	Females: Number	No. egg or embryo recovered (%)	Embryos: Unfertilized (%)	Embryos: Degenerating (%)	Embryos: Normal (%)
2 to 8	Heifer	72	9	15	15	61
	Cow	36	0	0	17	83
14 to 16	Heifer	30	27	0	3	70
	Cow	19	11	0	16	73

Beef Females Culled for Failure to Reproduce. One hundred thirty-two females of various breeds were culled in 1979 and 1980 for failure to maintain a pregnancy. Number and percentage of females culled by age are presented in Table 2. One-third of the females were heifers that failed to maintain a pregnancy. An equal percentage of 3-, 4-, and 6-year-old females were culled. Of the 132 females, 103 were observed for estrus and exposed to bulls for 25 days. The mated females were slaughtered on various days of gestation up to day 22. Their reproductive tracts were flushed with physiological saline to recover an embryo or oocyte. The results are presented in Table 3. The remaining 28 females were slaughtered but were not exposed to bulls because their reproductive tract did not feel normal upon palpation.

Unlike the cows presented in Table 1, the twice open females had a very high percentage of unrecoverable oocytes or embryos. This percentage of unrecoverable ova did not increase greatly with increased gestation length, indicating an early loss of the oocyte or embryo. The early loss of an oocyte or embryo indicates either a failure to collect the oocyte by the oviduct, accelerated oocyte transport through the reproductive tract, or defects in shedding the oocyte from the ovary. The uterine flushings were analyzed for total protein, zinc, and calcium. The

Table 2.—Number and ages of beef females culled in 1979 and 1980 for failure to reproduce after 2 exposures of 45 days to bulls

	Age 2	3	4	5	6	7	8	9
Number	43	20	17	15	20	9	4	4
Percentage of total culled	33	15	13	11	15	7	3	3

Table 3.—Recovery rate and percentage of abnormal and normal developing embryos in females culled for failure to reproduce

Number of females	Number with no recovery of an ova or embryo	Number with unfertilized oocytes or abnormal embryonic development	Number with normal development
103	55 (53%)	14 (14%)	34 (33%)

[1]Ralph R. Maurer is a research physiologist, at MARC.

Continued.

tability is increased by significant between herd genetic variation. Several generations of extensive outcrossing would introduce about half of the between herd genetic variance into a herd and increase heritability and effectiveness of individual selection in subsequent generations. However, accuracy of selection and genetic change during the outcrossing period would be reduced relative to use of progeny tested sires.

Estimates of heritability for percentage calving difficulty and survival were low. The estimates of heritability for survival traits (low, 4 to 14%), postweaning growth traits (moderate, 27 to 46%), and carcass traits (moderate to high, 23 to 52%) compare closely with previous estimates for similar traits. The heritability estimates for preweaning growth tended to be lower in this study (low, 5 to 15%) than in previous reports, possibly because all calves were raised by 2-year-old dams in the first year and by 2-year-old and 3-year-old dams in the second year, which provide a more limited maternal environment than cows of more mature ages.

flushings from females in which no oocyte or embryo was recovered generally had increased levels of protein, zinc, and calcium, which suggests that these females may have a hormonal imbalance.

Hormone Levels in Pregnant and Nonpregnant Females. Progesterone distribution within the reproductive tract. Ten beef cows were mated naturally at the onset of estrus and slaughtered 12 to 15 days later. Reproductive tracts were collected and six samples of tissue were collected from each reproductive tract—mesosalpinx, mesometrium, uterus (two locations), uterine artery, and bifurcated uterine artery. Each tissue sample was analyzed for progesterone content. The tissues on the same side as the corpus luteum had higher progesterone content than tissues from the opposite side. The tissues adjacent to the corpus luteum had higher levels of progesterone than tissue further from the corpus luteum. Therefore, a gradient of progesterone concentration exists within tissue from the reproductive tract. This gradient was similar in pregnant and nonpregnant females.

Hormonal asynchrony as a cause for fertilization failure and embryonic death. Twenty-four cows and 24 heifers were observed continuously for the onset of estrus. All females observed in estrus were either artificially inseminated or naturally mated. Blood samples were collected immediately after mating and every 4 hr for the first 40 hr and thereafter twice daily until slaughter at day 8 to 10 or 13 to 16 of gestation. Reproductive tracts were collected and flushed with physiological saline to recover an oocyte or embryo. Blood samples were analyzed for luteinizing hormone (LH) and progesterone concentration. All cows and 22 of 24 heifers were detected in estrus. Since we found no differences in hormone levels between cows and heifers, we combined all females and grouped them according to physiologic status. Seventeen females had normal developing embryos, 8 had unfertilized oocytes or degenerating embryos, 6 had no recovery of either an oocyte or embryo, and 15 failed to ovulate. Handling stresses, blood collection, and animal restraint probably contributed greatly to inhibit ovulation in the females that failed to ovulate.

Results from the analyses of blood serum for LH and progesterone content are presented in Table 4. Females with embryos developing normally had a higher LH peak height than females with unfertilized oocytes or degenerating embryos and females with no recovery of an oocyte or embryo. Progresterone content was greater in females with a normal embryo at day 3. At day 6 of gestation, progsterone levels were greater in females with a normal embryo than in females with an unfertilized oocyte of degenerating embryo. The reduced hormone concentration and delayed secretion of hormones may produce a uterine environment that is bad for the oocyte and the spermatozoa. Therefore, the end result is fertilization failure or embryonic death or both.

Table 4.—Luteinizing hormone and progesterone concentration in pregnant and nonpregnant females

Physiologic status	Number	Luteinizing hormone peak height (ng/ml)	Interval in hours from onset of estrus to LH peak height	Progesterone content (ng/ml)	
				Day 3	Day 6
Normal embryo	17	34.3±4.7	8.9±2.1	0.56±0.08	2.01±0.20
Unfertilized oocyte or degenerating embryo	8	11.8±6.8	13.7±3.7	.21± .03	.97± .18
No recovery of oocyte or embryo	6	13.3±2.5	13.5±6.2	.34± .12	1.96± .34

Mean ± standard deviation.

Table 5.—Superovulation of cows and heifers[1]

Breed	Number superovulated	Average number corpus luteum	Average number oocytes/embryos	Average number useable embryos	Percentage of females with useable embryos
Hereford:					
Heifers	21	6.6 (1-10+)	4.8 (0-16)	2.5 (0-12)	10/21 47.6
Cows	7	8.3 (7-10+)	7.3 (5-11)	5.1 (1-10)	7/7 100.0
Brown Swiss:					
Heifers	24	7.3 (2-12)	4.0 (0-11)	2.7 (0-9)	16/24 66.7
Cows	4	6.8 (4-10+)	7.5 (0-17)	1.8 (0-5)	2/4 50.0

[1]The response range is given in parentheses.

Table 6.—Summary of pregnancy rate by recipient breed and genotype

Embryo genotype	Breed of recipient: Brown Swiss	Breed of recipient: Hereford	Total
Brown Swiss ♂ x Hereford ♀	8/32 (25)	10/42 (24)	18/74 (24)
Hereford ♂ x Brown Swiss ♀	3/36 (8)	11/29 (38)	14/65 (22)
	11/68 (16)	21/71 (30)	32/139 (23)

Number pregnant / [1]Number transferred

[2]Numbers in parentheses are percentages.

Embryo Development After Embryo Transfer. Embryo transfer is being used commercially to increase the number of offspring from cows with high production. Embryo transfer is also an important tool in research to study embryonic development, uterine environment, and maternal contributions to embryonic development.

We collected embryos nonsurgically on day 8 of gestation from 28 Brown Swiss and 29 Hereford donors that had been injected with follicle stimulating hormone to induce superovulation. The Brown Swiss females were mated to Hereford males, and the Hereford females were mated to Brown Swiss males. Viable embryos were transferred nonsurgically to Brown Swiss and Hereford females on days 7, 8, and 9 of the estrous cycle.

The results of the superovulation are presented in Table 5. Average embryo recovery rates were 53.7% for Brown Swiss donors and 76.4% for Hereford donors. Pregnancy rates following embryo transfer are presented in Table 6. More Hereford cows maintained their pregnancy than Brown Swiss cows; however, genotype of the embryo and age of the recipient also influenced pregnancy rates. More 5-year-old cows maintained their pregnancy than did younger or older cows, but no cows 8 years of age or older maintained a pregnancy (Table 7). Therefore, breed of recipient, dissimi-

Continued at bottom of next page.

BLOOD FLOW TO THE UTERUS

Sherrill E. Echternkamp[1] and Stephen P. Ford

Summary

Pattern of blood flow to the bovine uterus was determined by using electromagnetic blood flow probes during the estrous cycle and early pregnancy to evaluate the effect of the early bovine conceptus on uterine blood supply. Pattern of blood flow through the middle uterine artery of pregnant and nonpregnant cows was similar until day 14 after mating or estrus. Between days 14 and 18 of pregnancy, blood flow to the uterine horn containing the conceptus increased two-to-threefold, whereas blood flow to the other uterine horn in these cows remained constant. By day 19 of pregnancy, blood to the pregnant horn had returned to the level on day 13. Blood flow to both uterine horns of pregnant cows was low from days 19 to 25 and then increased to the pregnant horn through the remainder of pregnancy. Uterine blood flow during the estrous cycle of nonpregnant cows was positively associated with systemic concentrations of estradiol, whereas during pregnancy blood flow was positively related with progesterone concentration. These data indicate local control of uterine blood flow by the bovine conceptus, which may function to create optimal conditions for the continuation of pregnancy.

[1]Sherrill E. Echternkamp is a research physiologist at MARC.

Continued.

larity of breeds between recipient, and donor and age of recipient all influenced survival of transferred embryos.

Table 7.—Nonsurgical embryo transfer in different aged cows

Age (years)	Brown Swiss	Hereford	Total
3	2/9 (22)	0/1 (0)	2/10 (20)
4	5/24 (21)	8/27 (30)	13/51 (25)
5	3/7 (43)	8/21 (38)	11/28 (39)
6	1/9 (11)	4/14 (29)	5/23 (22)
7	0/4 (0)	1/8 (13)	1/12 (8)
8	0/11 (0)	-----	0/11 (0)
9	0/2 (0)	-----	0/2 (0)
10	0/2 (0)	-----	0/2 (0)
	11/68 (16)	21/71 (30)	32/139 (23)

Pregnant
[1]Number transferred

[2]Numbers in parentheses are percentages.

Introduction

Maternal recognition of pregnancy in the cow requires the presence of a conceptus on day 15 to 17 after mating. The mechanism responsible for maintenance of the corpus luteum during early pregnancy, and the way in which the embryo influences the process, are not clearly understood but may involve a local effect of the conceptus on uterine blood flow. This experiment was conducted to see if the embryo does indeed stimulate synthesis of a factor that increases blood flow to the uterus.

Procedure

In an effort to determine if the early bovine conceptus could affect uterine blood supply, as well as characterize bloodflow pattern to the uterus during the estrous cycle, blood flow transducers were chronically implanted around both middle uterine arteries of six multiparous Hereford cows.

The flow transducer probes were surgically implanted around a segment of the middle uterine artery (from which a 1 cm segment of adventitia was removed), supplying each uterine horn before its first division in the mesometrium. The electrical connector of each flow transducer was exteriorized from the abdominal cavity through a small flank incision, attached to the skin over the incision site, and connected to a square-wave electromagnetic flow meter that displayed blood flow measurements (ml/min) at 15-sec intervals. Daily blood flow estimates were obtained by averaging the 15-sec measurements obtained during a daily 30-min monitoring period.

The cows were housed in stanchions except for daily AM and PM estrous detection. All cows were mated at the first estrus after placement of the probes. The cows were slaughtered after their return to estrus 21 days later (nonpregnant) or if no estrous activity, on day 30 to 35 after mating (pregnant). Pregnancy and placement of flow transducers were verified at slaughter. The uterine artery supplying blood to the uterine horn adjacent to the ovary with the corpus luteum was referred to as the ipsilateral artery, whereas the uterine artery supplying the other uterine horn was referred to as the contralateral artery. Jugular vein blood samples were collected daily via an indwelling cannula from each cow after the daily monitoring of uterine blood flow to determine serum estradiol 17 and progesterone by radioimmunoassay.

Results

Nonpregnant cows. Rates of uterine blood flow through the ipsilateral and contralateral uterine arteries did not differ significantly on any day during the estrous cycle in the nonpregnant cows; therefore, the ipsilateral and contralateral uterine arterial blood flow curves were pooled for the nonpregnant cows. Blood flow to the uterus of the three nonpregnant cows (Fig. 1) was highest from 2 days before onset of estrus to 1 day after estrus. Blood flow had decreased by day 2 (estrus = day 0) and gradually declined to day 6. All three nonpregnant cows exhibited two transient increases in uterine blood flow between days 7 to 15 of the cycle, followed by a decline on day 16, which preceded the rise in uterine blood flow 2 days before the subsequent estrus.

Serum concentrations of estradiol (Fig. 2) were highest at estrus, and two transient increases were observed during the luteal phase of the estrous cycle in all cows. The increases in serum estradiol coincided with increases in blood flow to the uterus, resulting in a positive relationship between serum estradiol and uterine blood flow in the nonpregnant cow. The positive relationship between serum estradiol and uterine blood flow may have resulted from the vasodilatory action of estradiol.

Pregnant cows. The pattern of blood flow to the uterus of pregnant cows was similar to that of nonpregnant cows until day 13 after mating (Fig. 3). Between days 14 and 18 of pregnancy, blood flow through the uterine artery supplying the pregnant horn increased two to threefold, whereas blood flow through the contralateral uterine artery remained constant. By day 19 of pregnancy, blood flow through the ipsilateral uterine artery had returned to a flow rate similar to that observed on day 13. Blood flow to both uterine horns of the pregnant cows remained constant from day 19 until day 25, when blood flow to the pregnant horn increased markedly to day 30. In contrast, blood flow through the contralateral uterine artery exhibited a progressive decline from day 24 to day 30.

From 0 to 19 days of pregnancy, concentrations of progesterone in the systemic blood followed a pattern similar to that observed during the estrous cycle of nonpregnant cows (Fig. 4). Instead of declining to a low level, as observed in nonpregnant cows on day 20, progesterone concentrations of pregnant cows remained high and relatively constant for

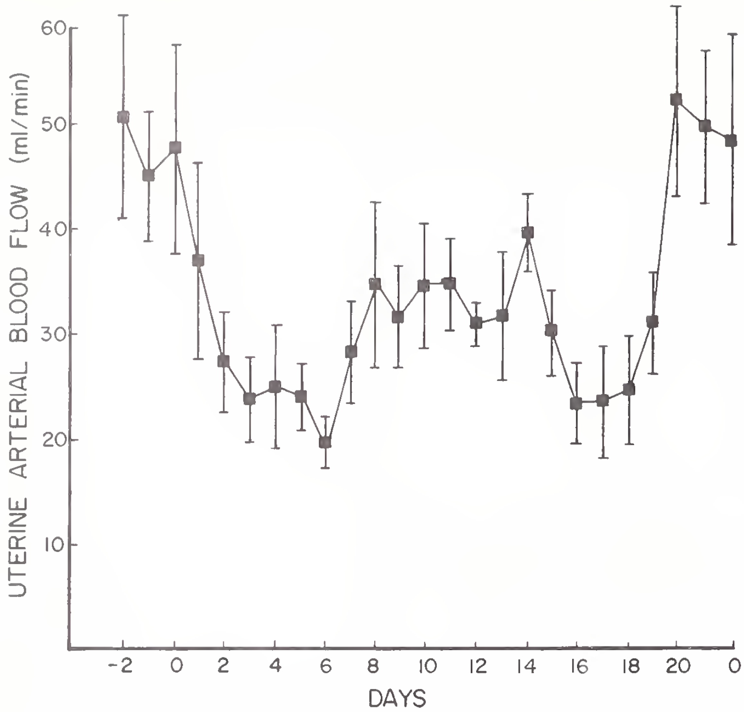

Figure 1.—Pattern of blood flow to uteri of 3 nonpregnant cows throughout the estrous cycle (day 0 = estrus). Each point represents the mean ± s.e.m. of 6 uterine arteries (3 ipsilateral and 3 contralateral).

The results of this study indicate local control of uterine blood flow by the early bovine conceptus. Failure of the contralateral uterine artery to exhibit a corresponding increase in blood flow on days 14 to 18 of pregnancy may reflect a unilateral signal initiated by the bovine conceptus and a differential sensitivity, or both, of the two uterine arteries for the signal that reduced constriction of the uterine artery supplying the pregnant horn. Also, blood flow to the pregnant horn of cows increased on the days critical for ensuring prolongation of life-span of the corpus luteum required for maintenance of pregnancy. Thus, it appears that the conceptus produces or stimulates uterine synthesis of a factor that dilates the utero-varian vasculature on the pregnant side, thus creating optimal conditions for continuing pregnancy.

the remainder of the 30-day monitoring period. As observed in the nonpregnant cows, estradiol concentrations in the blood of pregnant cows were highest at estrus followed by two transient peaks between days 5 and 8 and between days 14 and 17 of pregnancy. Concentrations of estradiol remained relatively constant from day 19 to day 30 of pregnancy.

Unlike the nonpregnant cows, no association could be demonstrated between blood flow through the ipsilateral or contralateral uterine arteries of pregnant cows during the first 30 days of pregnancy and systemic concentrations of estradiol. However, a positive correlation was observed between blood flow to the pregnant uterine horn and systemic concentrations of progesterone. In addition, the concentration of progesterone in the systemic blood of pregnant cows was higher than that of nonpregnant cows from day 14 to 18 after mating. Since blood concentrations of progesterone are a reliable measure of luteal function and blood flow to the corpus luteum, the conceptus-induced increases in blood flow to the pregnant uterine horn may be accompanied by increased blood flow through the corpus luteum, resulting in increased secretion of progesterone and a positive relationship between blood flow to the pregnant uterine horn and serum progesterone concentrations in the pregnant cow.

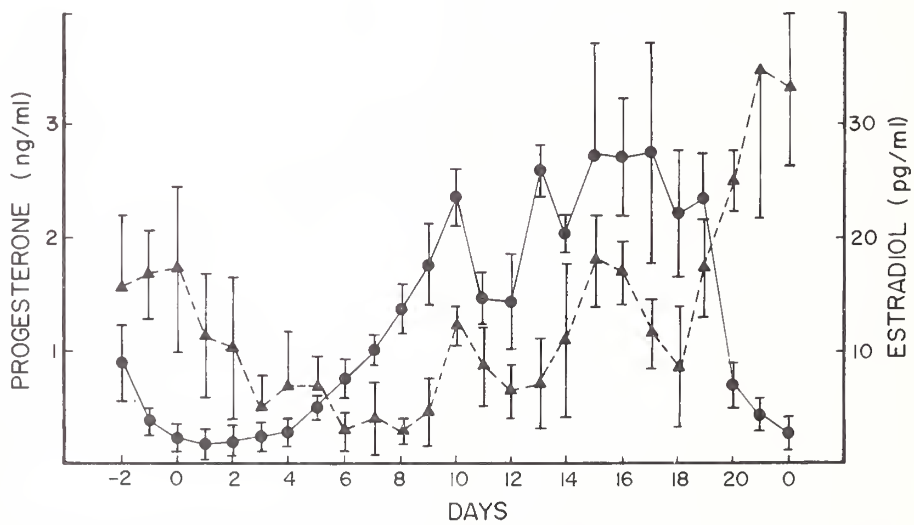

Figure 2.—Concentrations of progesterone (● — — — — — ●) and estradiol-17β (▲------▲) in systemic blood throughout the estrous cycle of 3 nonpregnant cows. Each point represents the mean ± s.e.m. Day o = estrus.

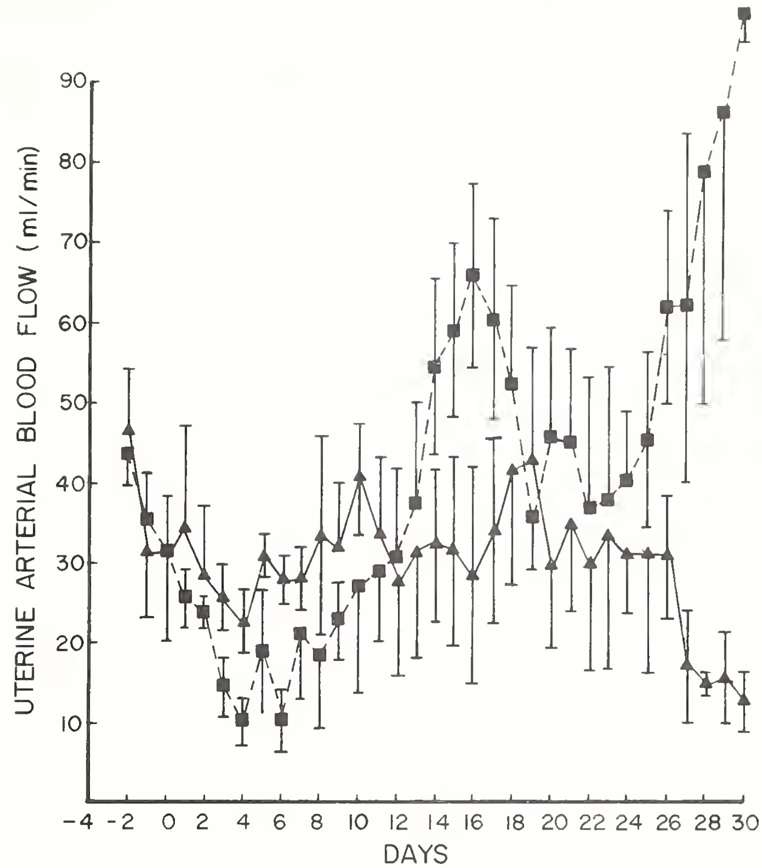

Figure 3.—Pattern of blood flow to both uterine horns of 3 cows throughout the first 30 days of pregnancy (day 0 = day of mating). Each point represents the mean ± s.e.m. for 3 gravid uterine horns (■-------■) and 3 non-gravid (▲— — — — — — —▲) horns.

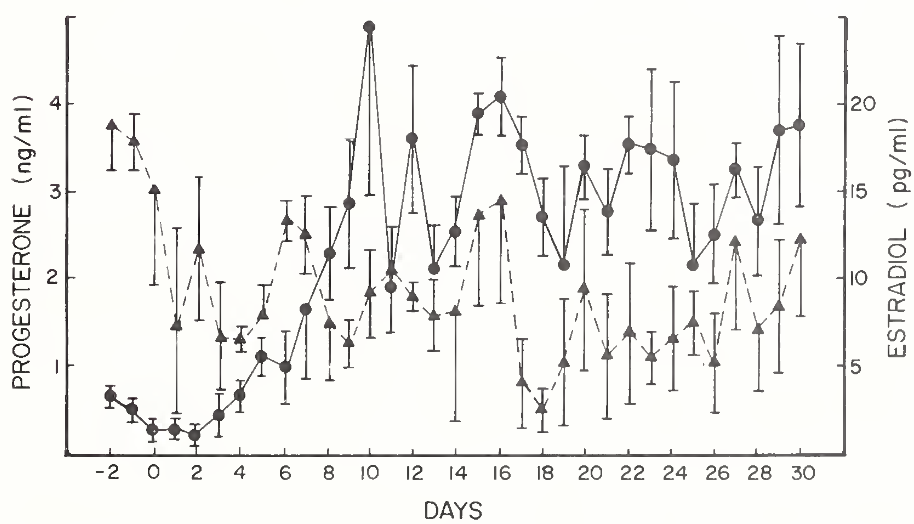

Figure 4. —Concentrations of progesterone (● — — — — — — —●) and estradiol-17β (▲------▲) in systemic blood of 3 cows throughout the first 30 days of pregnancy (day 0 = day of mating). Each point represents the mean ± s.e.m.

EFFECT OF PREGNANCY ON DISEASE RESISTANCE

Rita C. Manak[1]

Summary

During pregnancy, the immune response of cattle has an altered potential to overcome infection than during an open period. Several mechanisms seem to control this immune response, and they are being currently researched.

Introduction

During pregnancy, the dam's ability to respond to bacteria and viruses and to resist infection (its immune system) is altered somewhat to protect the developing fetus. While this system must continue to protect against infection, it must be modulated to avoid rejecting the fetus as if it were a growing foreign organ transplant. A disruption of this balance has impact on dam and fetal health as well as on embryo survival. Factors responsible for this interaction are not clearly understood. The purpose of these studies was (1) to assess the ability of the dam to respond to infectious-like agents as pregnancy progresses and (2) to determine if hormones that change in serum concentration during pregnancy affect this response.

Methods

We obtained lymphocytes (the cells mediating the immune response) from blood samples of six heifers at monthly intervals throughout the course of gestation. At the same sampling times, blood samples were also obtained from six ovariectomized (ovex) heifers as control for seasonal effects. All heifers were mixed breeds and were born the fall of 1978. The intact heifers were synchronized and bred June 23 to 25, 1980. The control heifers were ovariectomized in April 1980.

The lymphocytes were assayed for their ability to respond to two different immune stimulants: Concanavalin A (Con A) and Pokeweed Mitogen (PWM). In some studies, the response to these agents was determined in the presence and absence (controls) of physiological concentrations of estrogen, estrone, and progesterone.

Results

Table 1 summarizes the immune responsiveness of lymphocytes from pregnant heifers as a function of gestational stage, compared to responsiveness of control lymphocytes from ovex heifers. Figure 1 demonstrates the inhibiting effect of serum factors associated with pregnancy on immune responsiveness of lymphocytes obtained from pregnant heifers. Together, these data suggest that during pregnancy, the potential of the immune response to recognize and overcome infection is heightened. However, superimposed on that situation is the existance of soluble substances in the serum of pregnant animals, which can further regulate responsiveness. Thus, the immune response of pregnant animals appears to be under the control of several mechanisms.

To assess the role of soluble steroid hormones, which increase in the serum during pregnancy, lymphocytes from 200-day pregnant and ovex heifers were assayed in the presence of estrone, estrogen, and progesterone. Figure 2 shows that progesterone, estrone, and to a lesser extent, estrogen, are indeed capable of depressing lymphocyte responsiveness. Further work is in progress to define these regulatory mechanisms and its effects on the health status of the dam and her fetus.

Table 1.—Stage of pregnancy on lymphocyte responsiveness

Stage of gestation	Response of pregnant heifers / Response of ovex heifers X 100 (%)
Prebreeding	80
1st Trimester	130
2nd Trimester	160
3rd Trimester	190

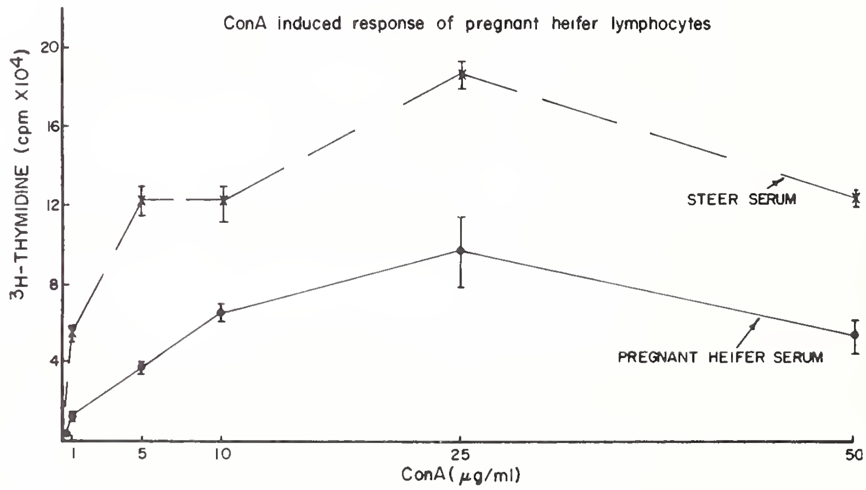

Figure 1.

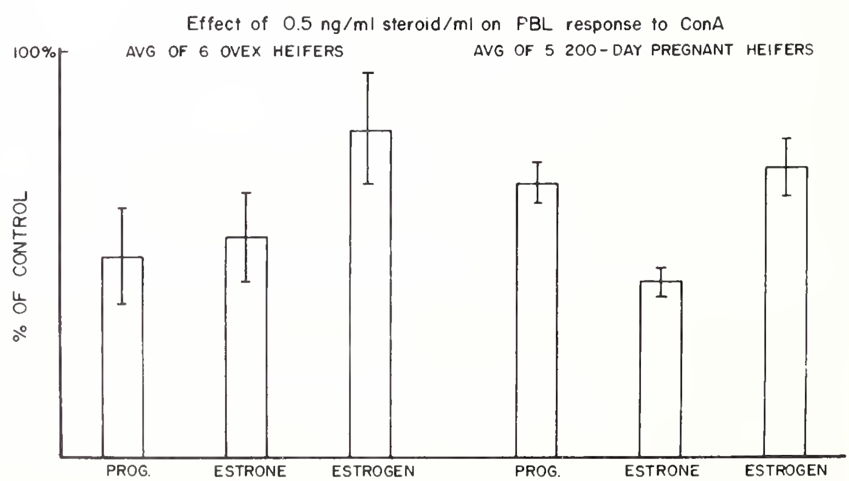

Figure 2.

[1]Rita C. Manak is a research physiologist at MARC.

PRELIMINARY OBSERVATIONS ON THE IMMUNE STATUS OF NEWBORN NORMAL AND WEAK CALF SYNDROME CALVES

Rita C. Manak[1] and William G. Kvasnicka

Summary

Thymus-derived lymphocytes from weather-stressed calves decline in response to Concanavalin A (Con A) and Pokeweed Mitogen (PWM) as the age of calf increases. Maximal response is from 24-hr old normal calves; very little response is from Weak Calf Syndrome (WCS) calves. This depressed response reflects the observed thymus degeneration in WCS calves and contributes to the animals' impaired immune system development.

Introduction

WCS is a collection of symptoms that includes severe weakness, difficulty in standing and subsequently nursing, swollen hock and carpal joints, bloody synovial fluid, susceptibility to secondary infection, and reddened muzzle. Upon postmortem examination, we observed enlarged and hemorrahagic lymph nodes and spleen, gastroenteritis, and degenerate thymus. Most weak calves are affected by 7 days of age and frequently die within 3 to 4 days. WCS appears to be associated with weather stress, and an increased frequency occurs during prolonged periods of cold, rainy weather. Seven percent of approximately 4,000 calves died with WCS symptoms during the cold, rainy 1980 calving season compared to less than 0.5% in the mild 1981 season. Because of the observed susceptibility to infection and abnormal lymphoid organs of affected calves, we assessed the immune status of WCS and normal calves.

Methods

Blood samples and thymus biopsy samples were obtained from age-paired normal and untreated WCS calves. Lymphocytes were enriched from the blood and from biopsy samples and assayed for their ability to respond to the immune stimulants Con A and PWM.

Results

Figure 1 shows that we observed no significant difference between peripheral blood lymphocytes of normal or weak calves nor an age dependent pattern of responsiveness. Similar patterns were observed with both Con A and PWM. However, Figure 2 shows that thymus-derived lymphocytes from normal calves respond maximally to Con A when obtained from 24 hr-old calves. This response declined by 10 days of age from one-third to one-sixth the observed response of peripheral lymphocytes. A similar pattern of decreasing responsiveness with age was observed with normal thymocytes when assayed with PWM. However, in contrast to thymocytes from normal calves, those from WCS calves showed very little response to either PWM or Con A (9% that of normal thymocyte Con A response and 11% normal thymocyte PWM response).

When cells from normal or WCS animals were assayed in the presence of WCS serum instead of normal serum, no differences were observed, indicating the absence of a serum-associated WCS factor.

The depressed response of the WCS thymus-derived lymphocytes would corroborate the increased susceptibility of these calves to such illnesses as pneumonia or scours. The immune system of cattle and of other mammalian species is incompletely developed at birth. Antibodies are present in very low levels in the calf and must be acquired from the dam through the colostrum within hours after birth. Development of the calf's own immune system continues from 6 months to a year after birth. In this process, the thymus plays an important developmental role, and its impairment would affect the animal's subsequent resistance to infection.

Thymus degeneration can be the result of malnutrition, either a general starvation or deficiency of a particular mineral, such as zinc. Prenatal virus infection causes a similar degenerate thymus in laboratory animals such as mice and could be causative in cattle WCS. The relative roles of these factors in WCS are not yet established, nor is the role of additional stress, such as weather stress, clearly understood.

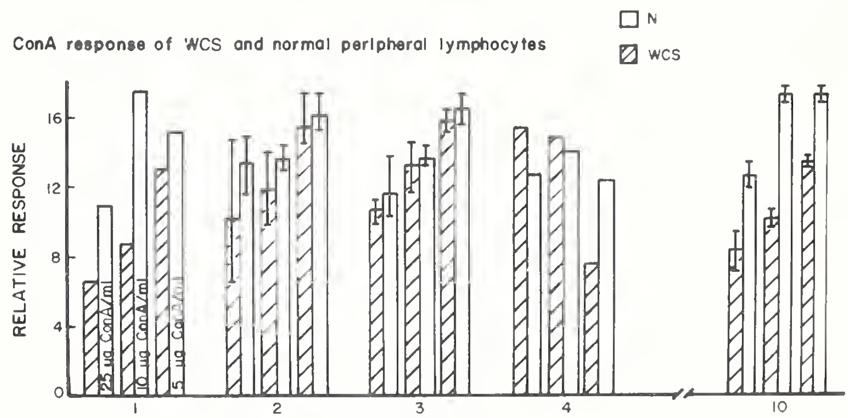

Figure 1.

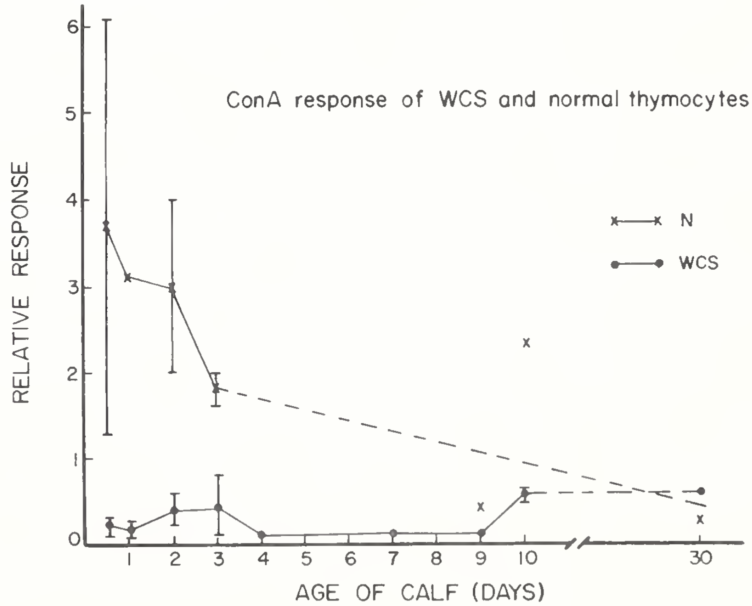

Figure 2.

[1]Rita C. Manak is a research physiologist at MARC.

DECREASING THE POSTCALVING ANESTROUS PERIOD IN SUCKLED BEEF HEIFERS

Sherrill E. Echternkamp[1]

Summary

The interval from calving to first ovulation was reduced to less than 45 days in 2-year-old suckled heifers by feeding a high energy diet (ADG, 1.4-2.5 lb/day) during the postcalving period or by a single injection of exogenous gonadotropin (2,250 IU PMSG) on day 42 postcalving. A comparison of reproductive parameters for heifers on the high and low energy (maintenance) diets during the postcalving period indicated that a higher percentage of heifers on the high energy diet had ovulated by 46 days post/calving (100 vs 0 %) and that both basal plasma luteinizing hormone (LH) concentration and estrogen-mediated LH release was increased during the early postcalving period. Results of these experiments suggest that the level of endogenous gonadotropin secretion may determine the length of the postcalving anestrous period and that plasma LH may be a useful parameter in establishing nutrition requirements for the postpartum lactating cow.

Introduction

Duration of the postcalving anestrous period can be influenced by lactation, nutrition, age of cow, breed of cattle, or a combination of these factors. The described experiments were conducted to determine how these factors affect ovarian and pituitary activity in the 2-year-old suckled heifer.

Procedure

Experiment 1: Two-year-old suckled Angus and Brown Swiss heifers, 12 of each breed, were treated with 750 or 2,250 IU of pregnant mare serum gonadotropin (PMSG) at 42 days postcalving to determine (1) cause(s) of previously observed breed differences in duration of the postcalving anestrous period, and (2) the relationship between postcalving reproduction and level of milk production. Peripheral blood samples were collected at 6-hr intervals for LH and estrogen and progesterone measurements to assess pituitary and ovarian response respectively. Daily milk production for each cow was estimated at 34, 40, and 60 days postcalving by the calf-weight change technique.

The relationship among dietary energy intake, ovarian follicular development, and ovarian and pituitary hormone secretion, during the postcalving period, was evaluated in 36 first calf Hereford heifers (Experiment 2). Sixteen of the heifers received a high energy diet (corn, corn silage, and soybean meal) during the precalving (last trimester) and postcalving period (approximate ADG 2.6 lb/day precalving and 1.6 lb/day postcalving), whereas the remaining 20 heifers received a maintenance ration. Peripheral blood samples were collected at 3-day intervals for LH, follicle stimulating hormone, prolactin, estrogen, and progesterone measurements. Heifers from both diets (4 high and 5 low) were ovariectomized at 10, 28, 46, and 70 days postcalving to evaluate follicular development and the occurrance of ovulation.

Results

The administration of 2,250 IU PMSG induced ovulation in all 12 heifers, whereas 8 of 12 heifers receiving 750 IU PMSG had ovulated within 10 days after the injection (Table 1). A breed comparison indicated that Brown Swiss produced more milk (mean overall difference, 4.9 lb/day) and had a longer interval from injection of 2,250 IU PMSG to occurrance of the preovulatory LH surge than Angus, which may indicate a negative relationship between milk production and pituitary responsiveness. Both breeds had increased ovarian and pituitary stimulation with 2,250 IU PMSG as compared with 750 IU.

Initiating reproduction cycles in the suckled Hereford heifers (Experiment 2) was influenced by dietary energy intake as 100% of the heifers on the high energy diet had ovulation by 46 days postcalving, whereas on the low energy diet (maintenance) 20% ovulated in the day 28 postcalving group, none in the day 46 group, and 40% in the day 70 group (Table 2). However, gross observations of follicular development at ovariectomy did not reveal a difference in the number of follicles (grouped by size) or in mean ovarian weights. A comparison of plasma LH concentrations and estrogen-mediated LH surges between the two dietary groups indicated that the heifers on the high energy diet had increased basal plasma LH concentrations (3.3 vs 2.4 ng LH/ml plasma). Additional hormone analyses of blood and follicular fluid samples are in progress. Calf birth weight tended to be increased by the higher energy precalving diet (68 vs 63 lb).

Results from these two experiments suggest that length of the interval from calving to first ovulation is inversely related to level of endogenous gonadotropin stimulation. Therefore, increased dietary energy intake increases basel LH secretion which, in turn, enhances ovarian and pituitary hormone secretion and the spontaneous induction of ovulation. Additional experiments are being planned to further evaluate the relationship between nutrition and postpartum reproduction.

Table 1.—Ovarian and pituitary response to PMSG in anestrous cows at 42 days postpartum

Treatment[1]	Number ovulating	Interval from PMSG to LH surge (hours)	Maximum preovultory e_2 concentration (pg/ml)
750 IU of PMSG:			
Angus	3	[2] 82.0 ± 12.2	[2 3] 8.7 ± 1.3
Brown Swiss	5	[2] 69.6 ± 7.0	[2 3] 8.3 ± 1.5
Mean		[2] 74.3 ± 6.2	[2 3] 8.4 ± 1.0
2,250 IU of PMSG:			
Angus	6	[3] 55.0 ± 3.9	[2] 8.6 ± .7
Brown Swiss	6	[2] 68.0 ± 4.0	[3] 12.1 ± 1.3
Mean		[2 3] 61.5 ± 3.3	[2 3] 10.4 ± .9

[1]Each treatment group contained 6 cows. Time interval between LH surge and ovulation is approximately 24 h.
[2 3]Significance with a column at P<0.05.

[1]Sherrill E. Echternkamp is a research physiologist at MARC.

Table 2.—Effect of dietary energy on postpartum reproduction in beef heifers

Time of ovariectomy	Number of cows	Number ovulating	Basal LH concentration (ng/ml)	Estrogen-mediated LH surge (ng/ml)
Day 10 postpartum:				
Low energy diet	5	0	2.3	32.8
High energy diet	4	0	3.3	53.9
Day 28 postpartum:				
Low energy diet	5	1	2.0	66.5
High energy diet	4	0	2.9	93.0
Day 46 postpartum:				
Low energy diet	5	0	2.2	58.7
High energy diet	4	4	3.7	109.2
Day 70 postpartum:				
Low energy diet	5	2	3.1	74.5
High energy diet	4	4	3.4	109.2
Overall:				
Low energy diet	20	3	2.4	58.1
High energy diet	16	8	3.3	90.1

TESTICULAR DEVELOPMENT AND ONSET OF PUBERTY IN BEEF BULLS

Donald D. Lunstra[1]

Introduction

Selection and management of young beef bulls have been hampered by a lack of information on reproductive development, growth, and puberty. The use of an increasing number of sire breeds in the beef cattle industry has placed additional emphasis on the importance of defining differences in sexual maturation within and among breeds. We conducted the following studies as part of a program designed to characterize reproductive development and puberty in breeds of beef bulls.

Pubertal Traits in Beef Bulls. We studied pubertal development in Hereford, Angus, Red Poll, Brown Swiss, Hereford-Angus crossbred (HxA), and Angus-Hereford crossbred (AxH) bulls from 7 through 13 months of age. Pubertal factors characterized included body weight, testicular size, sperm produced, and sexual aggressiveness. Each trait was measured every 2 weeks from December through June. Puberty was defined as the age at which a bull first produced an ejaculate containing at least 50 million sperm with a minimum of 10 percent motility. Brown Swiss (264 days) and Red Poll (283 days) bulls reached puberty earliest, Angus bulls (295 days) and crossbred bulls (AxH, 296; HxA, 300 days) were intermediate, and Hereford bulls (326 days) were latest to reach puberty (Table 1). Brown Swiss bulls were heaviest (649 lb), while Red Poll (568 lb) and Hereford (574 lb) bulls were lightest in body weight at puberty.

Although rather large differences in age and body weight at puberty existed among breeds of bulls, scrotal circumference at puberty among and within breeds did not differ ($P>.10$) and averaged 11.0 ± 0.1 in at puberty in all bulls (Table 1). The range of scrotal circumference at puberty was 10.2 to 11.8 in, and 52% of the bulls reached puberty at $\leq$ 11.0 in, 74% at $\leq$ 11.5 in, and 100% at $\leq$ 12.0 in. Scrotal circumference is an accurate measurement of testicular size and *is easily* obtained. We concluded that scrotal circumference may be a useful tool for selecting early maturing beef bulls with minimal effort. However, the effects of different nutritional planes and management practices on pubertal and testicular development remain to be investigated.

Breed Differences in Testis Size of Yearling Bulls. Scrotal circumference was measured in yearling Angus, Hereford, Gelbvieh, Brown Swiss, Red Poll, Simmental, Charolais, and Limousin bulls and compared to data collected in previous studies on pubertal age of heifers. Pubertal age in heifers was defined as age at first standing heat (first estrus). Testis size (Table 2), measured as scrotal circumference, was largest in yearling bulls of breeds in which heifers reached puberty the earliest (Gelbvieh, Brown Swiss, and Red Poll), intermediate among breeds in which heifers reached puberty at intermediate ages (Angus and Simmental), and smallest among breeds in which heifers reached puberty the latest (Hereford, Charolais, and Limousin). The correlation between heifer pubertal age and yearling bull scrotal circumferences was 0.98 among breed means. Yearling scrotal circumference was affected significantly by breed, sire, age of dam, and body weight of bulls. Scrotal circumference and body weight was smaller in bulls from 2-year-old dams than from older dams. Adjustment of scrotal circumference for yearling body weight essentially nullified the effect of age of dam but increased the heritability estimate for scrotal circumference from 0.52 to 0.69, and significant effects of breed and sire remained. A large range in yearling scrotal circumference existed within each breed (Table 2). Based on the relatively high heritability of testis size, the relationship between testis size and age at puberty, and the range of testis size present within breed, selection of bulls for larger yearling testis size may provide a means for rapid improvement in pubertal age within breeds of beef cattle.

[1]Donald D. Lunstra is a research physiologist at MARC.

Table 1.—Pubertal characteristics of various breeds of beef bulls[1]

Pubertal trait	Breed group						
	Hereford	Angus	H x A crossbred	A x H crossbred	Red Poll	Brown Swiss	All bulls[2]
Number of bulls evaluated	5	5	6	5	5	5	31
Age in days at:							
First sperm	266	265	258	268	252	236	258 ± 2
50 million sperm[3]	326	295	300	296	283	264	294 ± 4
First completed mating	371	354	366	341	333	250	336 ± 5
Body weight in pounds at:							
First sperm	491	543	535	535	513	598	535 ± 9
50 million sperm[3]	574	601	614	581	568	649	601 ± 9
First completed mating	625	708	730	669	645	623	671 ± 13
Scrotal circumference (inches) at:							
First sperm	9.4	10.8	9.8	10.5	10.1	10.3	10.2 ± .2
50 million sperm[3]	11.0	11.3	10.9	11.2	10.8	10.9	11.0 ± .1
First completed mating	11.5	12.2	12.0	12.0	11.6	10.7	11.7 ± .1

[1]Least-squares means.
[2]Data given as mean ± SEM.
[3]Based on first production of an ejaculate containing at least 50 million sperm with a minimum of 10 percent motility.

Table 2.—Breed comparisons: bull testicular size *versus* heifer age at puberty

Breed	Heifer age at puberty (days)[1]	Scrotal circumference of yearling bulls[2] Average (inches)[3]	Range (inches)
Gelbvieh	341 ± 9 (81)	13.7 ± 0.2 (22)	11.9-16.6
Brown Swiss	347 ± 8 (126)	13.5 ± .2 (19)	12.2-15.6
Red Poll	352 ± 8 (95)	13.2 ± .2 (20)	11.7-14.6
Angus	372 ± 10 (24)	12.9 ± .2 (79)	10.3-15.1
Simmental	372 ± 6 (157)	12.9 ± .3 (28)	10.3-15.4
Hereford	390 ± 13 (27)	12.1 ± .2 (55)	10.3-14.2
Charolais	398 ± 7 (132)	12.0 ± .3 (31)	10.0-14.8
Limousin	398 ± 6 (161)	11.9 ± .2 (20)	9.6-13.5
Average	368 ± 3 (723)	12.7 ± .1 (274)	
Heritability	.41	.52	

[1]Least-squares means ± standard error. Number of heifers measured is given in parentheses. Data from Germ Plasm Evaluation Project (Cycle I, II, and III).
[2]Data from Germ Plasm Utilization Project and adjusted to 365 days of age.
[3]Least-squares means ± standard error. Number of bulls measured is given in parentheses.

SEXUAL AGGRESSIVENESS IN BEEF BULLS

Donald D. Lunstra[1]

Introduction

Large differences in conception rate during pasture-mating can exist among beef bulls having semen of acceptable quality. Based on data from artificial insemination, we know also that conception rate increases as the number of inseminations increases, and it is probable that conception rate to natural mating increases as number of matings per cow increases. Sexual aggressiveness (libido) is a behavioral factor that can influence the number of matings a bull can achieve and, thus, may influence the conception rate obtained during natural mating. Accurate evaluation of sexual aggressiveness and its relationship to fertility may provide useful information for selecting young beef bulls with high breeding potential. We conducted the following studies to investigate sexual activity in young beef bulls during a series of libido tests and to evaluate the relationship between libido test activity and fertility during natural mating.

Procedure

Libido Testing. Fifty yearling Hereford bulls that had been subjected to similar managerial and environmental influences since birth were evaluated for sexual aggresiveness. Bulls were allotted at random into subgroups of five bulls and subjected to six 30-min libido tests during a 21-day period (tested once every 4 days). For each test, five bulls were exposed to four ovariectomized, estrus-induced heifers for 30-min, and sexual behavior (mounts and matings) was recorded for each bull.

Semen was evaluated and scrotal circumference was measured on all bulls following libido testing. We eliminated five bulls from the study for lack of physical soundness, and we analyzed sexual aggressiveness for the remaining 45 bulls (Fig. 1). The 45 bulls exhibited a continuous increase in percent bulls mating during the first three libido tests (Fig. 1). Number of matings per bull per test also increased during the first three tests. These data indicate that yearling bulls undergo a learning process or acclimation to the test environment during initial libido tests, and that at least two libido tests are required before sexual activity of yearling bulls becomes stabilized. Large differences in mating activity existed among the bulls tested. Four bulls (9%) exhibited no sexual interest during libido testing, 8 bulls (19%) were classified as low libido bulls (0.4 ± 0.1 matings/test), 19 bulls (42%) were classified as medium libido bulls (1.5 ± 0.1 matings/test), and 14 bulls (31%) were classified as high libido bulls (2.6 ± 0.2 matings/test).

Four bulls with similar, acceptable semen quality were selected from each of the groups of bulls classified as low, medium, or high libido. Only bulls that had mated during libido tests were selected from each libido class. Each of the 12 selected bulls was individually exposed to 50 heifers and allowed to mate at will for 20 days. Low libido bulls mated significantly fewer of the heifers in estrus (71%) than did medium libido (95%) or high libido (87%) bulls (Table 1). Based on palpation at 50 days after exposure to a bull, conception rate per heifer in estrus (Table 1) was significantly lower for low libido bulls (33%) than for medium (50%) or high libido bulls (51%). The decreased conception rate for low libido bulls appeared to be directly related to their decreased ability to detect and mate all heifers in estrus. No significant difference in conception rate was observed between medium and high libido bulls (Table 1). The correlation between scrotal circumference and conception rate was not significant ($r = 0.40$). The correlation between conception rate/bull and number of matings/libido test/bull was highly significant ($r = 0.68$). We concluded that the sexual activity expressed by bulls in libido tests was related positively to the conception rate achieved by these bulls during single sire fertility trials. Testing and selecting bulls for acceptable sexual aggressiveness may provide an effective tool for identifying bulls with superior breeding potential.

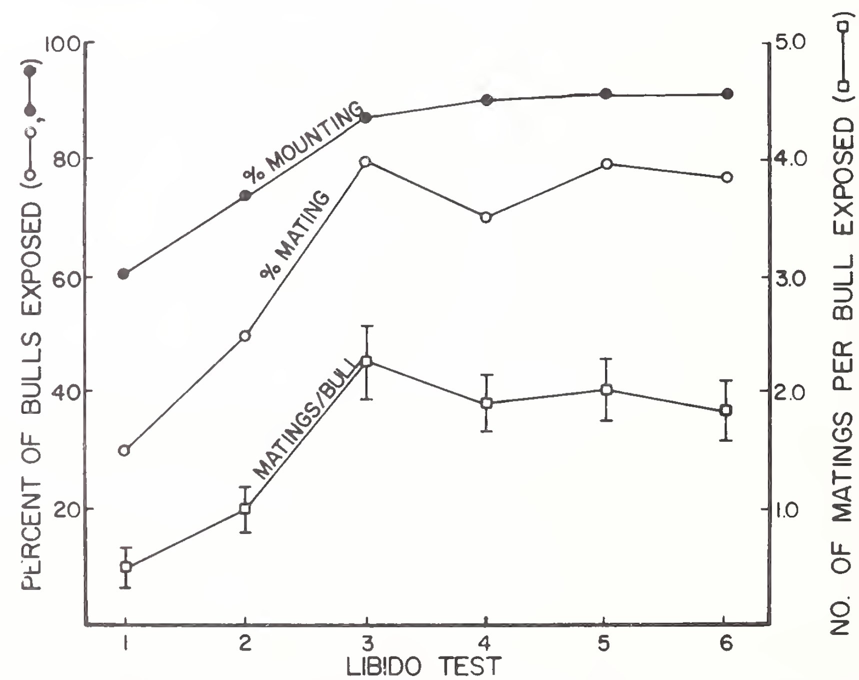

Figure 1.—Mounting and mating activity of 45 yearling bulls subjected to six 30-minute libido tests.

Table 1.—Mating and conception rate for individual bulls exposed to 50 cyclic heifers for 20 days[1]

Bull libido group	Number of bulls	Number of heifers exposed	Heifers exhibiting estrous (%)	Estrous heifers mated (%)	Conception rate/heifer exposed (%)	Conception rate/estrous heifer (%)
High	4	198	[2]90	[2]87	[2]46	[2]51
Medium	4	200	[2]96	[2]95	[2]48	[2]50
Low	4	202	[2]93	[2]71	[3]30	[3]33

[1]Each bull was exposed to approximately 50 heifers for 20 days (single-sire, natural mating).
[2,3]Percentage values without a common footnote within a column are different ($P<0.01$).

[1]Donald D. Lunstra is a research physiologist at MARC.

PERFORMANCE CHARACTERISTICS OF FEEDLOT BULLS AND STEERS IMPLANTED WITH ESTRADIOL-17β

Bruce D. Schanbacher[1] and Ronald L. Prior

Summary

Bulls were shown to grow more rapidly (+18%) and convert feed to live weight gain more efficiently (22% less feed) when compared to steers. Whereas bulls had larger loin eye areas and yielded a higher percentage of major retail cuts, marbling scores and quality grades were similar for bulls and steers. Implants containing estradiol-17β dipropionate had no major effects on performance characterisitcs of steers but reduced the performance of bulls to approximately that of steers. Our research shows that estradiol can suppress performance of feedlot bulls by inhibiting testosterone secretion from the testes.

Introduction

Castrating meat-producing animals has long been a traditional practice in the United States. The increasing demand for animal protein and decreasing demand for animal fat, however, have placed renewed emphasis on the production potential of intact bulls. Under most, if not all, management systems, bulls grow more rapidly, utilize feed resources more efficiently, and produce more lean red meat than steers. Testicular hormones are thought to be responsible for the performance attributes of intact bulls; however, the predominant steroid secreted by the testis, testosterone, may not be the key hormone in this regard. Estradiol-17β, which is secreted by the bovine testis and is produced by peripheral aromatization of testicular androgen, is a physiologically potent steroid. This natural occurring estrogen, as well as such synthetic estrogens as diethylstilbestrol (DES), have been tested experimentally and used commercially to stimulate growth and improve feed utilization in beef cattle. The following study was conducted (1) to determine the relative performance differential between bulls and steers and (2) to determine whether these two groups of cattle respond to estradiol-17β supplement.

Procedure

Forty Angus and 40 Pinzgauer x Hereford crossbred bull calves, born in late March and weaned in October, were assigned in equal numbers to one of four treatment groups including (1) bulls, (2) steers, (3) bulls implanted with a Silastic capsule containing estradiol-17β dipropionate, and (4) steers implanted with a Silastic capsule containing estradiol-17β dipropionate. Calves were fed and maintained by treatment in groups of five. Two weeks after the respective treatments were imposed (Dec. 5), we began to collect data by recording initial weights.

Live weights, feed intake, testicular diameters, and jugular blood samples were taken at 28 day intervals until June 17, at which time all animals were taken to slaughter. Estradiol capsules were removed from implanted animals on April 23 to insure an adequate time period for steroid withdrawal. Hot carcass weight and cooler data were recorded for each animal.

Results

The performance characteristics of bulls and steers, nonimplanted and implanted, are presented in Table 1. Neither sex treatment nor estradiol treatment affected initial weight, whereas, both treatments affected ($P<0.05$) average daily gain and final weight. Feed efficiency differed ($P<0.05$) for bulls and steers but was not affected by estradiol. Feed intake was not affected by either treatment. These findings confirm that bulls grow more rapidly and gain weight more efficiently than steers, but they provide controversial findings regarding the proposed anabolic actions expected of estrogens in feedlot cattle.

Sex treatment had a significant ($P<0.05$) influence on all carcass traits except for adjusted backfat thickness and marbling scores. Bulls had heavier carcasses, larger loin eye areas, and lower yield grade scores (i.e., a greater percentage of boneless retail cuts) than steers. On the other hand, reduced kidney-pelvic fat was associated with lower quality grade scores.

Estradiol treatment reduced loin eye area of bulls but not steers, whereas estradiol treatment reduced ($P<0.05$) the percentage kidney-pelvic fat, marbling score, and quality grade in both bulls and steers. The negative influence of estradiol on carcass traits was similar to its negative influence on growth rate and feed efficiency.

The effect of castration and estradiol treatment on serum concentrations of luteinizing hormone (LH) and testosterone are presented in Table 2. Whereas bulls are characterized by low serum LH and high serum testosterone, steers are characterized by the reverse: low or nondetectable serum testosterone and high serum LH. Interestingly, treatment with the naturally occurring estrogen, estradiol-17β, appears to block testosterone secretion by the testes. This inhibition is accompanied by reduced serum LH and reduced testis size. Implant removal re-

Table 1.—Effect of castration and estradiol-17β treatment on growth rate, feed utilization, and carcass traits in the male bovine[1]

	Bull		Steer	
	- implant	+ implant	- implant	+ implant
Growth:				
Initial wt _ _ _ lb _ _ _	550.2 ± 10.6	544.5 ± 10.2	528.4 ± 10.1	525.8 ± 10.1
Final wt _ _ _ lb _ _ _	1162.3 ± 20.9	1060.8 ± 19.8	1043.9 ± 19.8	1008.7 ± 19.8
ADG _ _ _ lb/day _ _ _	3.12 ± .09	2.64 ± .09	2.64 ± .09	2.46 ± .09
Feed data:				
Dry matter intake lb/day _ _ _	16.94 ± .51	16.96 ± .51	16.19 ± .51	17.69 ± .51
Feed efficiency lb/lb _ _ _	4.97 ± .36	5.91 ± .36	6.42 ± .36	6.41 ± .36
Carcass data:				
Hot carcass wt _ _ _ lb _ _ _	734.7 ± 14.1	683.6 ± 13.4	642.2 ± 13.4	623.4 ± 13.4
Kidney-pelvic fat _ _ _ %	2.22 ± .12	1.99 ± .2	2.70 ± .12	2.10 ± .12
Backfat thickness _ _ _ in	.38 ± .03	.39 ± .03	.43 ± .03	.40 ± .03
Marbling score[2] _ _ _	9.1 ± .45	7.2 ± .43	9.1 ± .43	7.9 ± .43
Quality grade[3] _ _ _ _	8.0 ± .34	6.5 ± .32	8.5 ± .32	7.8 ± .32
Longissimus area[2] _ _ in	13.5 ± .26	12.4 ± .25	11.7 ± .25	11.6 ± .25
Yield grade[4] _ _ _ _ _ _	2.3 ± .14	2.5 ± .13	2.8 ± .13	2.6 ± .13

[1]Data presented as least squares means ± standard error of mean of 18 or 20 animals
[2]Marbling score, slight = 7, 8, 9, small = 10, 11, 12
[3]Quality grade score: good = 7, 8, 9; choice = 10, 11, 12
[4]Yield grade score high cutability = 1, low cutability = 5

Continued at bottom of next page.

[1]Bruce D. Schanbacher is a research physiologist at MARC.

BLOOD FLOW AND NUTRIENT UPTAKE OF THE BOVINE UTERUS AND FETUS

Calvin L. Ferrell,[1] Ronald L. Prior, Ronald K. Christenson, and Stephen P. Ford

Summary

Basic knowledge of the nutritional and hormonal requirements for normal development of the fetus and other gravid uterine tissues is essential to establish bases from which to study factors that may contribute to abnormal fetal development. Despite recognition of this necessity, few data are available that describe blood flow to the gravid uterus of cows. Data obtained by Ferrell and Ford (1980) indicated blood flow to the gravid uterus was 75, 155, 154, 105 and 60 ml/min/kg at 80, 140, 180, 210, and 240 days of gestation. Silver and Comline (1975) reported blood flow to be 312 ± 20 ml/min/kg gravid uterus in cows during late gestation. Blood flow to the gravid uterus in cows was about 14% of cardiac output, which compares favorably to the estimate of 15.7% in sheep. The estimate obtained by Silver and Comline would represent about 35% of cardiac output. It is probable that the estimates of Ferrell and Ford (1980) were underestimates and those of Silver and Comline (1975) were overestimates of uterine blood flow.

Introduction

Data obtained in sheep demonstrate that glucose is a primary energy source of gravid uterine tissues. Glucose oxidation in these and other studies represented about 50% of fetal energy expenditures. Catabolism of amino acids to urea represented about 25% of total energy expenditures. Studies in cows indicated catabolism of amino acids to urea represented about 50% of the energy available from absorbed glucose, but data were not available that would allow determination of the relationship between glucose or amino acid catabolism to total energy expenditures. Data from sheep have demonstrated that the utero-placental unit utilized a large portion of absorbed glucose and that both the uterine and fetal tissues synthesize glucose from lactate as well as from amino acids. The objectives of the present study were to characterize rate of blood flow and nutrient uptake of the bovine uterus and fetus.

[1]Calvin L. Ferrell is a nutritionist at MARC.

Table 1.—Mean metabolite concentrations and arterial-venous differences in maternal and fetal blood[1]

Metabolite	Maternal: Uterine Artery	Maternal: UA-UV	Fetal: Umbilical Vein	Fetal: UM-FA
Oxygen, MM	6.295 ± 0.040	.665 ± 0.027	3.170 ± 0.067	1.040 ± 0.054
Glucose, MM	2.50 ± .036	.132 ± .011	1.34 ± .023	.127 ± .011
Lactate, MM	.806 ± .057	-.023 ± .006	2.067 ± .063	.174 ± .002
α Amino nitrogen, Meq/1	17.11 ± .31	.407 ± .015	35.16 ± .44	.736 ± .264
Urea nitrogen, Meq/1	6.94 ± .16	-.057 ± .036	7.28 ± .18	-.143 ± .005

[1]Oxygen, glucose, and lactate values were obtained from whole blood samples and α-amino nitrogen and urea nitrogen. Values were obtained from plasma samples.

Procedure

Mature (5-7 year old) Hereford cows were obtained from the MARC herd. Cows were naturally mated to Angus bulls and breeding dates were recorded. Surgery was performed on 16 cows at 171 ± 1 days post-mating. Cows were placed on a surgery table and mid-ventral incision was made to expose the uterus. Indwelling catheters were then placed in an artery (UA) and a vein (UV) on the surface of the gravid uterine horn. An incision was then made in the uterus and the fetus was exposed. Indwelling catheters were then placed in a fetal femoral artery (FA), fetal femoral vein (FV), and umbilical vein (UM). Beginning 2 days post-surgery, blood samples were taken from the UA, UV, FA, and UM catheters. Plasma was obtained and later analyzed for glucose, α-amino-nitrogen, and urea nitrogen. On day 6 post-surgery, antipyrene (25g/100ml) was infused into the FV catheter as a pulse (10ml) followed by a 3.5-hr continuous infusion (0.191/ml/min). Blood samples were taken from the UA, UV, FA, and UM catheters before infusion and at 1, 1½, 2, 2½, 3, and 3½ hr after the infusion began. Blood samples were analyzed for antipyrene, glucose, lactate, and oxygen immediately after collection. Uterine blood flow was estimated as RI/UV-UA and umbilical blood flow was estimated as RI/FA-UM, where RI was the antipyrene infusion rate and UV, UA, FA, and UM represented antipyrene concentrations in blood from the uterine vein, uterine artery, umbilical vein, and fetal femoral artery catheters, respectively. Uptake of each nutrient by the gravid uterus was estimated as UA-UV concentration difference times uterine blood flow and by the fetus as UM-FA concentration difference times umbilical blood flow.

Results

Concentrations of oxygen, glucose, lactate, α-amino-nitrogen, and urea nitrogen (Table 1) in the uterine artery and umbilical vein indicate glucose and oxygen concentrations were lower in fetal than in maternal circulation but that lactate, α-amino nitrogen, and urea nitrogen were higher in fetal circulation. The differences between uterine arterial and uterine venous concentration indicate oxygen, glucose, and α-amino nitrogen (amino acids) were taken up by the uterus but that lactate and urea were excreted by the uterus into the maternal circulation. The umbilical vein-fetal femoral artery concentration differences indicated a net flow of oxygen, glucose, lactate, and α-amino nitrogen from the utero-placental

Continued at bottom of next page.

Continued.

sulted in a marked increase in serum LH in steers and a marked increase in serum testosterone and testes size in bulls. These findings suggest that the poor performance of estradiol-implanted bulls may not be a direct result of estrogen but a secondary one caused by negative influences imposed by estrogen on the pituitary-testicular endocrine axis. Although this conclusion may not necessarily reflect the results obtainable with each and every estrogen proposed as a growth stimulant, the findings do suggest one mechanism whereby estrogen can, in fact, suppress the performance potential of feedlot cattle.

Table 2.—Concentrations of serum luteinizing hormone and testosterone and testis diameters in estradiol-17β treated bulls and steers[1]

Treatment	LH (ng/ml)	Testosterone (ng/ml)	Testis diameter (mm)
Bull			
(- implant)	3.1 ± 0.3	4.9 ± 0.4	67.4 ± 0.7
(+ implant)	2.1 ± .2	.4 ± .2	46.1 ± 1.4
Steer			
(- implant)	6.4 ± .3	.2 ± .1	-----
(+ implant)	2.1 ± .1	.2 ± .1	-----

[1]Data presented as means ± standard error of mean of 18 or 20 animals. Data taken at the time of implant removal, for example, 13 months of age.

EFFECT OF BREED AND POSTWEANING RATE OF GAIN ON ONSET OF PUBERTY AND PRODUCTIVE PERFORMANCE OF HEIFERS

Calvin L. Ferrell[1]

Introduction

Age at puberty is an important production trait in beef cattle where heifers are bred to calve at 2 years of age, especially when a restricted breeding season is used. It is not only important that heifers breed and conceive, but, for maximum efficiency, they should breed and conceive early in the breeding season. Thus, age at puberty may be an important selection trait for identifying breeds most suited for efficient utilization of feed resources. Several researchers have demonstrated large differences among breed or breed cross in age at puberty of heifers. Other researchers have demonstrated that undernutrition may result in increased age at puberty, subnormal conception rate, and underdeveloped udders. Overfeeding, however, may result in weak heat symptoms, subnormal conception rate, high embryonic mortality, decreased mammary gland development, and decreased milk production. Thus, proper nutrition during the developmental period may have both short and long term effects on heifer productivity. The purposes of the present study were to describe the effects of breed and postweaning growth rate on the onset of puberty, milk production, and productivity of heifers.

[1]Calvin L. Ferrell is a nutritionist at MARC

Procedure

Angus (A, 68), Hereford (H, 93), Red Poll (R, 61), Brown Swiss (B, 47), Charolais (C, 36), and Simmental (S, 90) heifers were used in a study designed to evaluate the effects of breed and postweaning rate of gain on the onset of puberty and subsequent productive performance. Heifers were grouped at weaning such that one-third of the A, H, and R (small) heifers were fed in each of three pens as were one third of the B, C, and S (large) heifers. One pen of heifers of each type was fed to gain at either a low (L, 0.9 lb/day), medium (M, 1.3 lb/day), or high (H, 1.8 lb/day) rate. Heifer weights were determined at 28-day intervals throughout the 184-day feeding period and periodically thereafter. Hip height was measured. At the end of the 184-day feeding period, approximately one-half of each group of heifers was moved to pasture and one-half was kept in the feedlot through breeding (70 days), then moved to pasture. Puberty was evaluated by twice daily visual observation from about 1 month post-weaning through the breeding period. All heifers were managed under typical management conditions after breeding. Date of parturition, calf birth weight, and survivability were evaluated. Milk production of a sample of six heifers from each breed and post-weaning treatment group was determined at approximately 50, 90, and 130 days postpartum by the weigh-suckle-weigh technique. Cow rebreeding performance and calf weaning weight were evaluated.

Results

Heifer weight (Table 1) differed among breeds at all times. Increased

Continued on next page.

Continued.

unit to the fetus. There was a net flow of urea from the fetus to the utero-placental unit, however.

Estimates of uterine and umbilical blood flow have been presented in Table 2, as well as estimates of metabolite uptake by the gravid uterus and fetus. These results have been presented diagramatically in Figure 1. These results indicate about 72% of the oxygen taken up by the gravid uterus was utilized by the uterus and placenta and that about 28% actually reached the fetus. Similarly only 17% of the glucose and 32% of the α-amino nitrogen absorbed by the uterus from the maternal circulation actually reached the fetus. A relatively large portion (25%) of the glucose metabolized by the utero-placental tissues was converted to lactate. Lactate was then apparently excreted to both the fetal and maternal circulations. About 20% of the α-amino nitrogen taken up by the fetus was excreted, as urea, to the utero-placental tissues, but only 8% of the α-amino nitrogen retained by the utero-placental tissues was converted to urea and excreted into the maternal circulation. These data suggest a rapid rate of nitrogen (or protein) retention in both fetal and uterine-placental tissues at this stage of gestation.

These data demonstrate that uterine and placental tissues utilize a major portion of nutrients absorbed from the maternal circulation. Glucose appears to be the major energy source for these tissues at 177 days of gestation in the cow. Glucose, lactate and amino acids are major energy substrates for the fetus. These nutrients are major contributors to fetal growth as well.

Table 2.—Blood flow and metabolite uptake of the gravid bovine uterus and fetus

Item	Uterine	Umbilical
Blood flow, ml/min	6098 ± 380	1094 ± 59
Oxygen uptake, m mole/min	4.06 ± .16	1.138 ± .059
Glucose uptake, m mole/min	.805 ± .067	.139 ± .012
Lactate uptake, m mole/min	-.140 ± .037	.190 ± .024
α Amino-nitrogen uptake, meq/min	.248 ± .09	.805 ± .289
Urea-nitrogen uptake, meq/min	-.348 ± .220	-.156 ± .005

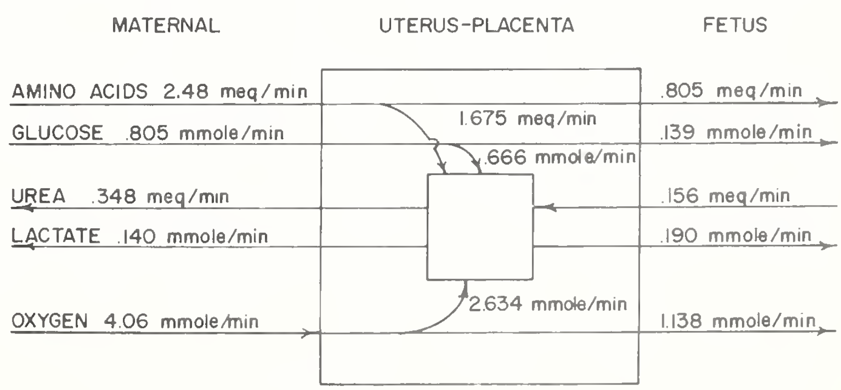

Figure 1.—Model of net flows of various metabolites through the gravid bovine uterus.

nutrition levels postweaning resulted in increased heifer weight and height. These differences were large immediately after the postweaning nutritional treatment but decreased thereafter. No differences in heifer weight were observed, due to postweaning nutritional treatment, at 930 days of age (after weaning first calf), indicating the nutritional treatments had no long-term effects on heifer weight.

Average age at puberty for Angus, Hereford, Red Poll, Brown Swiss, Charolais, and Simmental heifers was 409, 430, 359, 329, 390, and 351 days, respectively, and weight at puberty was 703, 677, 456, 675, 787, and 728 lb. Heifers fed the low, medium, and high rations were 393, 366, and 370 days of age and weighed 657, 692, and 785 lb at puberty. These results demonstrated breeds differ widely in both age and weight at puberty. Breeds that have been selected for high levels of milk production tended to reach puberty earlier than those selected for beef. These results also demonstrate postweaning nutrition can have a large influence on both age and weight at puberty. The low level of feeding resulted in delayed puberty, however, no advantage of the high level of feeding over the medium was observed.

Calf birth weight (Table 2) was influenced by breed but not by heifer nutritional level postweaning. Milk production differed among breeds and among nutritional treatments at 50 days postpartum (Table 3). Similar trends were observed at 90 and 130 days postpartum. Calf weaning weight was different among breeds (Table 2) and among heifer nutritional treatment groups. A large portion of the nutritional treatment differences was due to small differences in date of birth since all calves were weaned at a similar time.

These results demonstrate large breed differences among breeds for growth, puberty, and productivity traits. It should be emphasized, however, that the breed ranking for these characteristics varies depending on environmental and management conditions. In this study, for example, productivity favored heifers having high levels of milk production, however, productivity of these heifers would be expected to be less favorable on more limiting pasture situations. Effects of postweaning nutrition were primarily short-term in nature, however, data were presented that indicated low nutrition levels postweaning resulted in delayed onset of first estrus and somewhat decreased milk production. Conversely, data were presented that demonstrated that no long-term advantages resulted from feeding heifers to gain 1.8 lb/day postweaning. In fact, the data suggested some detrimental effects of high postweaning nutritional treatment.

Table 1.—Effect of breed, postweaning nutritional treatment, and subsequent management on heifer weight [1,2]

Main effect	No.	198	Age (Days) 382	403	450	550	635	930
Breed:								
Angus	78	^{4}432 ± 4	^{5}690 ± 7	^{5}708 ± 7	^{5}774 ± 7	^{4}776 ± 7	^{4}913 ± 9	^{4}946 ± 13
Hereford	93	^{3}395 ± 4	^{4}624 ± 7	^{4}655 ± 7	^{4}723 ± 7	^{3}739 ± 7	^{3}867 ± 7	^{4}957 ± 11
Red Poll	61	^{3}397 ± 4	^{3}613 ± 7	^{3}646 ± 7	^{3}706 ± 9	^{3}732 ± 9	^{3}867 ± 9	^{3}900 ± 13
Brown Swiss	47	^{7}507 ± 7	^{6}754 ± 9	^{6}778 ± 9	^{6}862 ± 9	^{5}904 ± 9	^{5}1034 ± 11	^{5}1012 ± 15
Charolais	36	^{5}485 ± 7	^{8}781 ± 9	^{7}805 ± 9	^{7}880 ± 11	^{6}926 ± 11	^{6}1105 ± 13	^{7}1195 ± 20
Simmental	90	^{6}494 ± 4	^{7}765 ± 7	^{8}783 ± 7	^{6}867 ± 7	^{5}902 ± 7	^{5}1041 ± 7	^{6}1105 ± 11
Nutrition treatment:								
Low	131	454 ± 4	^{3}628 ± 4	^{3}657 ± 4	^{3}725 ± 7	^{3}796 ± 7	^{3}946 ± 7	1003 ± 11
Medium	138	452 ± 4	^{4}710 ± 4	^{4}739 ± 4	^{4}803 ± 7	^{4}838 ± 7	^{4}981 ± 7	1023 ± 9
High	136	450 ± 4	^{5}774 ± 4	^{5}789 ± 4	^{5}869 ± 7	^{5}853 ± 7	^{5}986 ± 7	1028 ± 11
Management:								
Feedlot	200	452 ± 2	710 ± 4	^{4}754 ± 4	^{4}814 ± 4	^{3}823 ± 4	^{3}961 ± 4	1008 ± 9
Pasture	205	450 ± 2	701 ± 4	^{3}703 ± 4	^{3}789 ± 4	^{4}836 ± 4	^{4}981 ± 4	1028 ± 9

[1]Mean weight in pounds ± SE.
[2]Nine Angus, 13 Hereford, 2 Red Poll, 5 Charolais, and 8 Simmental heifers did not conceive during the breeding season so were not included at 635 or 930 days of age. One additional Red Poll, 4 Brown Swiss, and 1 Charolais were removed prior to 930 days of age.
[3 4 5 6 7 8]Means within a main effect and column with different superscripts differ ($P<0.05$).

Table 2.—Effects of heifer breed and postweaning nutritional treatment on calf birth date, birth weight and weaning weight [1]

Main effect	Number born	Birth date	Birth weight (lb)	Number weaned	Adjusted weaning weight (lb)
Breed:					
Angus	69	^{3}93 ± 5	^{4}71 ± 1	59	^{3}421 ± 7
Hereford	70	^{3}90 ± 5	^{4}70 ± 1	62	^{2}377 ± 7
Red Poll	61	^{2}76 ± 6	^{3}75 ± 1	52	^{4}454 ± 7
Brown Swiss	47	^{2}77 ± 7	^{5}90 ± 2	35	^{6}518 ± 9
Charolais	35	^{4}100 ± 8	^{6}95 ± 2	22	^{5}485 ± 11
Simmental	85	^{3}93 ± 5	^{4}84 ± 1	63	^{6}516 ± 7
Nurtitional treatment:					
Low	114	89 ± 4	81 ± 1	94	$^{2\,3}$465 ± 7
Medium	125	84 ± 4	82 ± 1	106	^{3}472 ± 7
High	128	92 ± 4	80 ± 1	93	^{2}450 ± 7

[1]Mean ± SE.
[2 3 4 5 6]Means within a main effect and column with different superscripts differ ($P<.05$).

Table 3.—Effects of breed of heifer and postweaning nutrition treatment on milk production and calf weight [1]

		Days postpartum: 50		90		130	
	No.	Calf weight (lb)	Milk production (lb/day)	Calf weight (lb)	Milk production (lb/day)	Calf weight (lb)	Milk production (lb/day)
Breed:							
Angus	18	^{4}174 ± 7	^{4}18 ± 1	^{4}267 ± 9	^{4}14 ± 1	^{4}342 ± 11	^{4}13 ± 1
Hereford	16	^{3}139 ± 7	^{3}13 ± 1	^{3}210 ± 9	^{3}11 ± 1	^{3}271 ± 11	^{3}11 ± 1
Red Poll	17	^{4}176 ± 7	^{5}20 ± 1	^{4}273 ± 9	^{4}15 ± 1	^{4}362 ± 11	^{5}16 ± 1
Brown Swiss	18	^{6}216 ± 7	^{8}28 ± 1	^{6}329 ± 7	^{6}23 ± 1	^{5}421 ± 9	^{6}20 ± 1
Charolais	17	^{5}199 ± 7	^{6}22 ± 2	^{5}302 ± 9	^{4}15 ± 1	^{5}399 ± 11	^{4}13 ± 1
Simmental	17	^{5}199 ± 7	^{7}25 ± 1	^{5}307 ± 9	^{5}19 ± 1	^{5}410 ± 11	^{5}17 ± 1
Nutrition treatment:							
Low	35	185 ± 4	^{3}19 ± 1	284 ± 7	15 ± 1	373 ± 7	15 ± 1
Medium	35	190 ± 4	^{4}23 ± 1	287 ± 7	17 ± 1	377 ± 9	15 ± 1
High	33	176 ± 4	^{3}20 ± 1	271 ± 7	16 ± 1	355 ± 9	16 ± 1

[1]Mean SE.
[2]Twenty-four hr milk production was estimated as the differences in calf weight before and after nursing, after being penned separate from the dam for 12 hr, times 2.
[3 4 5 6 7 8]Means within a main effect and column with different superscripts differ ($P<0.05$).

ELFAZEPAM AND SYNOVEX-S INFLUENCES ON GROWTH AND CARCASS CHARACTERISTICS OF STEERS FED TWO DIETARY ENERGY LEVELS

Ronald L. Prior,[1] John D. Crouse, and Virden L. Harrison

Summary

Synovex-S improves the average daily gain and carcass traits of steers and reduces losses under high feed price levels when compared to nonimplanted steers. High energy diets also influence average daily gain (ADG) favorably, but they increase the amount of fat and decrease the protein in carcass soft tissue in comparison to low energy diets.

Introduction

Under present market conditions, the use of growth-promoting implants or feed additives that improve gain or feed efficiency can be the difference between profit and loss in many feeding operations. Synovex-S (200 mg of progesterone and 20 mg of estradiol benzoate) improves ADG and feed efficiency in steers.

The use of stimulants in feed intake may have desirable effects on the performance of growing animals, particularly where voluntary intake is not adequate to provide sufficient net energy for gain. Alkyl-sulfonylalkyl-1- substituted benzodiazepines have been shown to elicit feeding in satiated animals. Voluntary intake is of particular concern in high-roughage diets where intake is limited by fill. In addition to the feeding response elicited by Elfazepam, it has been reported that administering Elfazepam to sheep fed a constant amount of feed increased the digestibility of the diet.

Procedure

The objectives of this study were to determine the effect of Elfazepam on growth and carcass characteristics of steers fed rations of two energy densities with corn silage as the forage base and to study possible interactions with Synovex-S implants. Corn silage represented 81.7% of the dry matter in the low energy diets and 19.7% in the high energy diets, resulting in 5.7 and 6.8 Mcal metabolizable energy per pound for the two diets. Elfazepam was added to the diet to provide about 8 mg/head/day. Steers were fed to 1,122 lb pen mean weights. Adding Elfazepam to the diet decreased rate of gain of steers by 9% compared to controls not receiving Elfazepam.

Results

Steers implanted with Synovex-S had a 27% greater ADG, a heavier hot carcass weight, and less kidney and pelvic fat than nonimplanted steers (Table 1). The trend toward a decreased quality grade from Synovex-S implant in the present experiment approached statistical significance. We noted no significant two-way interactions between dietary energy level, Synovex-S implant, or Elfazepam in growth or carcass composition traits.

The effect of Synovex-S implants was highly significant both from a biological and an economic standpoint. These implants made the difference between profits and losses under the low feed price level and reduced the losses under the high feed price level. Although Synovex-S resulted in similar yield grades and lower quality grades, this lowering of steer value per 220 lb was offset by a 27% increase in ADG. Under the low feed price level, net returns per steer per day were $0.113 higher for steers implanted with Synovex-S than for nonimplanted steers.

Ration energy level significantly influenced ADG. Steers fed the high energy diet had more kidney and pelvic fat and more estimated fat and less protein in carcass soft tissue than steers fed the low energy diet. The other carcass traits measured were not significantly influenced by dietary energy levels.

[1]Ronald L. Prior is a research chemist at MARC.

Table 1.—Main effects of Elfazepam, Synovex-S implant, and dietary energy level on steer performance and carcass traits[1]

Item	Elfazepam		Synovex-S implant		Dietary energy level	
	−	+	−	+	Low	High
Number of steers	109	108	107	110	110	107
Initial weight, lb	765.4 ± 4.4	762.3 ± 4.4	764.9 ± 4.6	762.7 ± 4.2	765.2 ± 4.4	762.5 ± 4.4
Slaughter weight, lb	1119.1 ± 7.0	1120.0 ± 7.0	1079.1 ± ^{2}7.3	1160.1 ± ^{3}6.8	1135.2 ± ^{3}7.0	1102.0 ± ^{2}7.0
Days on feed	134.3 ± 24.1	144.8 ± 20.2	139.5 ± 14.7	139.5 ± 14.7	164.5 ± 20.4	115.5 ± 13.1
Overall average daily gain, lb	2.79 ± ^{3}.04	2.55 ± ^{2}.04	2.35 ± ^{2}.04	2.99 ± ^{3}.04	2.31 ± ^{2}.04	3.04 ± ^{3}.04
Hot carcass weight, lb	666.8 ± 4.8	673.0 ± 4.8	674.0 ± ^{2}5.1	692.8 ± ^{3}4.8	672.8 ± 4.8	667.3 ± 5.1
Adjusted fat thickness, in	.46 ± .02	.43 ± .02	.44 ± .02	.44 ± .02	.43 ± .02	.46 ± .02
Longissimus area, in^2	12.2 ± .2	11.9 ± .2	12.2 ± .2	11.9 ± .2	12.0 ± .2	12.2 ± .2
Kidney and pelvic fat, %	2.95 ± .08	2.78 ± .08	2.99 ± ^{3}.09	2.74 ± ^{2}.08	2.76 ± ^{2}.08	2.97 ± ^{3}.08
Marbling[4]	10.57 ± .37	10.76 ± .36	11.18 ± .42	10.16 ± .35	11.10 ± .36	10.24 ± .37
Quality grade[5]	9.45 ± .19	9.50 ± .19	9.70 ± .22	9.25 ± .18	9.61 ± .18	9.35 ± .19
Yield grade	2.94 ± .10	2.90 ± .10	2.90 ± .12	2.94 ± .10	2.93 ± .10	2.91 ± .10
Estimated soft tissue composition %						
Fat	35.00 ± ^{3}.51	33.81 ± ^{2}.51	33.90 ± .59	34.88 ± .49	33.23 ± ^{2}.50	35.58 ± ^{3}.52
Protein	14.30 ± ^{2}.14	14.78 ± ^{3}.14	14.73 ± ^{3}.16	14.36 ± ^{2}.13	15.06 ± ^{3}.13	14.03 ± ^{2}.14
Moisture	50.96 ± .38	51.47 ± .38	50.89 ± .44	51.53 ± .36	51.18 ± .37	51.24 ± .39

[1]Data presented as least-squares means ± standard error of the mean. Carcass quality and composition traits were adjusted by analysis of covariance to a hot carcass weight of 685.3 lb
[2,3]Means within a treatment without a common superscript differ ($P < .05$).
[4]Marbling score: slight = 7, 8, 9; small = 10, 11, 12.
[5]Quality grade score: good = 7, 8, 9; choice = 10, 11, 12.

ENERGY UTILIZATION BY MATURE COWS

Calvin L. Ferrell[1] and Thomas G. Jenkins

Introduction

Although considerable effort has been directed toward describing nutrient requirements for maintenance and gain in growing-finishing beef cattle, relatively little effort has been made to establish nutrient requirements for these functions in mature beef cows. A high proportion (about 60%) of the feed resources required for beef production can be attributed to maintenance of the cow herd, thus more information is needed on the utilization of nutrients for maintenance and gain and how these parameters are affected by size and type of cow.

Procedures

Twelve mature, nonpregnant, nonlactating cows of each of four types (Hereford x Angus and Angus x Hereford, Jersey x Angus and Jersey x Hereford, Charolais x Angus, and Charolais x Hereford, and Simmental x Angus and Simmental x Hereford) were selected. These breed crosses were chosen to represent medium and large type cows with ability to produce either a moderate or high level of milk. Cows were randomly assigned, within type, to one of three pens (12 pens of 4 cows each) and individually fed either a low (130 kcal ME/W¾ daily), medium (190 kcal/W¾ daily), or a high (ad libitum) level. The diet consisted of corn silage (90%), soybean meal (9.1%), TM salt (0.5%), dicalcium phosphate (0.32%) and vitamin A, D, and E premix (0.08%) and contained 2.53 kcal ME/kg and 12% crude protein. Cows were weighed at the beginning of the study and at 28-day intervals thereafter. Cows were fed a total of 140 days beginning in December.

[1]Calvin L. Ferrell is a nutritionist at MARC.

Results

Weights of cows of different types and fed different levels after 0, 70, and 140 days on feed are presented in Table 1. Jersey cross cows weighed less initially and subsequently than cows of other breed crosses. Angus-Hereford cross cows were heavier than Jersey cross cows but lighter than Charolais or Simmental cross cows. Cows fed the low and medium rations were fed at constant levels, based on weight, thus feed intakes were primarily a reflection of cow weight in these groups. Simmental cows ate more than other types of cows, when fed ad libitum, followed by Angus-Hereford cross and Jersey cross cows. Charolais cross cows ate the least when fed ad libitum. Estimated feed requirements to maintain the weight of Angus-Hereford cross, Jersey cross, Charolais cross, and Simmental cross cows were 8.6, 10.6, 6.3, and 12.8 lb dry feed per day, respecitvely. When expressed as kcal ME/W¾ daily, the values obtained were 112, 157, 85, and 154 for these types of cows, respectively, suggesting breed differences in feed required to maintain cow weight may be of sufficient magnitude to be of importance. Feed required to maintain weight of mature cows was also estimated for each half of the feeding period. These results indicated 191 kcal ME/W¾ daily was required to maintain weight of cows, across all breed crosses, during the interval 0 to 70 days, but only 112 kcal/W¾ daily was required to maintain cow weight during the interval from 70 to 140 days, thus the feed required to maintain cow weight during the winter months was substantially higher (70%) than during the spring months.

Table 1.—Weight and daily dry matter intake of mature, nonpregnant, nonlactating cows

Item	Breed	Diet Low (lb)	Medium (lb)	High (lb)
Initial weight	AHX	1151	1147	1189
	CX	1250	1292	1277
	JX	1001	1003	1028
	SX	1184	1237	1343
Weight, day 70	AHX	1054	1180	1358
	CX	1136	1277	1405
	JX	893	957	1160
	SX	1098	1204	1491
Weight, day 140	AHX	1030	1252	1453
	CX	1105	1343	1427
	JX	864	1023	1226
	SX	1061	1288	1605
Daily feed intake day 0-70	AHX	13	17	30
	CX	11	19	25
	JX	11	15	26
	SX	13	18	29
Daily feed intake day 70-140	AHX	8	14	26
	CX	9	15	21
	JX	7	13	23
	SX	8	15	27

LIPID SYNTHESIS IN THE BEEF ANIMAL

Ronald L. Prior[1] and Stephen B. Smith

Summary

Rates of *in vitro* fat synthesis from acetate and lactate were compared to the activities of enzymes thought to be involved in the process of lipid synthesis from lactate. Results of these studies indicate that lactate can be incorporated into fats by a pathway heretofore thought to be nonfunctional in ruminants, the citrate cleavage:malic enzyme pathway. Studies of the effects of age and diet on the enzymes of the citrate cleavage:malic enzyme pathway support the concept of a physiological role for this pathway in lipid synthesis in beef cattle.

[1]Ronald L. Prior is a research chemist at MARC.

Introduction

Acetate, absorbed from the gastrointestinal tract of ruminants has historically been considered the only significant precursor for fat synthesis in the bovine animal. Recent studies in this and other laboratories, however, demonstrate that lactate can be converted to fats at appreciable rates in ruminant adipose tissue in the whole animal as well as in the laboratory. Lactate can either be absorbed from the gastrointestinal tract or produced by other tissues of the body for use by the adipose tissue. The only known route for converting lactate to fatty acids is the citrate cleavage:malic enzyme pathway. This pathway, however, has been considered to be nonfunctional in bovine adipose tissue because of the low activities of enzymes in the citrate cleavage:malic enzyme pathway relative to those observed in nonruminant adipose tissue.

We designed initial experiments to determine whether or not key enzymes in the citrate cleavage:malic enzyme pathway had enough activity to support rates of lipid synthesis from lactate observed in the laboratory. Subsequently, studies were undertaken to determine if age and diet could affect the activities of these enzymes.

Continued on next page.

Table 1.—Composition of pelleted diets[1]

Ingredient	Ration 1 (roughage)	Ration 2 (high concentrate)
Ground alfalfa hay	100	9.71
Ground corn	---	78.69
Soybean meal	---	5.05
Calcium chloride	---	1.10
Trace mineralized salt	---	.45
Binder (lignin sulfate)	---	5.00
Vitamins ADE[2]	---	+
		100.00

[1]Percent on as fed basis.
[2]Added to provide 22,000 IU A, 2,200 IU D, and 220 IU E per lb diet.

Experimental Procedure

Experiment 1. Samples of subcutaneous adipose tissue (backfat) were obtained by biopsy technique from Angus-Hereford crossbred finishing steers (1063 ± 31 lb) fed a high-energy ration. We then analyzed samples for the rate of fat synthesis from either acetate or lactate. A portion of each biopsy sample was homogenized, and crude centrifugal fractions of the homogenates were used for the analysis of enzyme activities.

Experiment 2. Twenty Angus-Hereford and Red Poll steers were divided into two groups of 10 animals each. Both groups were initially fed a ration consisting of pelleted sun-cured alfalfa hay. When the steers were approximately 250 days of age, one group was gradually switched to a pelleted high concentrate diet (Table 1). Biopsy samples of subcutaneous fat were obtained every 35 to 70 days, homogenized, and analyzed for enzyme activities.

Table 2.—Acetate and lactate incorporated into fatty acids in bovine subcutaneous adipose tissue

Substrates[1]	Incorporation rates (nmol/min per g adipose tissue)
10 mM Acetate	8.2 ± 2.5
plus 2mM Glucose	30.2 ± 6.3
10 mM Lactate	33.3 ± 6.5
plus 2 mM Glucose	47.5 ± 6.3

[1]Flasks that contained glucose also contained 33 mu/ml of insulin.

Results

Experiment 1. Rates of incorporation of acetate and lactate into fatty acids are listed in Table 2. Even though acetate is thought to be the major precursor for lipid synthesis in beef cattle, we incorporated lactate into fats at rates that exceeded those from acetate in both the absence and presence of glucose. Our research shows that lactate might be an important substrate for fat synthesis in whole animals.

Citrate cleavage enzyme, malic enzyme, and pyruvate carboxylase activities are listed in Table 3. The activities of the enzymes, all of which are involved in the citrate cleavage:malic enzyme pathway, are about one-tenth of the activities observed in nonruminant adipose tissue. All three enzymes, however, exhibit sufficient activity to account for the rates of lipid synthesis from lactate (Table 2).

Furthermore, the activities of citrate cleavage enzyme, malic enzyme, and pyruvate carboxylase are equal to or exceed that of acetyl-CoA carboxylase. Acetyl-CoA carboxylase has been shown to be involved in lipid synthesis from acetate and presumably is required for lipid synthesis from lactate. Therefore, the citrate cleavage:malic enzyme pathway should not be considered nonfunctional merely because key enzymes in this pathway are low in the adipose tissue of beef animals relative to those in nonruminants.

Experiment 2. As is typically observed, steers fed the high-concentrate diet grew at a faster rate than those on the alfalfa hay ration (Table 4). The activities of acetyl-CoA carboxylase, citrate cleavage enzyme, and malic enzyme were extremely low at the first biopsy. Enzyme activities increased gradually until the steers were 420 days old. Between 420 and 489 days of age, the activities of acetyl-CoA carboxylase and citrate cleavage enzyme abruptly increased two- to fourfold in the alfalfa hay-fed steers and eight- to tenfold in the high concentrate-fed steers. Enzyme activities declined significantly after 540 days of age. Malic enzyme activity doubled in the alfalfa hay-fed steers and tripled in the high concentrate-fed steers between 315 and 350 days of age. After 420 days of age, malic enzyme activity remained constant in the alfalfa hay-fed steers but had doubled in the high concentrate-fed steers by 489 days of age. The data indicate that the activities of lipogenic enzymes are not influenced by diet in beef cattle until the animals reach a specific age, corresponding to the time at which enzyme activities are increasing independently of dietary regime. Furthermore, citrate cleavage enzyme and malic enzyme responded to changes in age and diet in the same manner as acetyl-CoA carboxylase, supporting the concept of functional, biologically important, citrate cleavage:malic enzyme pathway.

Table 3.—Lipogenic enzyme activities in bovine subcutaneous adipose tissue

Enzyme	Maximal activity (nmol/min/g adipose tissue)
Citrate cleavage enzyme	78.8 ± 10.1
Malic enzyme	207.4 ± 23.5
Pyruvate carboxylase	42.4 ± 4.9
Acetyl-CoA carboxylase	54.0 ± 15.8

Table 4.—Effect of age and diet on lipogenic enzyme activities

Treatment group	Average age (days)	Weight (lb)	Enzyme activities (nmol/min/g adipose tissue) AcCoA carboxylase	Citrate cleavage enzyme	Malic enzyme
		(lb)			
I	280	575 ± 16	1.8 ± 0.9	2.6 ± 0.7	21.9 ± 1.9
II		534 ± 13	1.9 ± 1.1	1.9 ± .7	21.1 ± 3.4
I	315	640 ± 19	4.7 ± 1.9	1.8 ± .2	31.5 ± 4.3
II		595 ± 12	8.9 ± 2.2	2.3 ± .3	29.3 ± 4.4
I	350	704 ± 23	8.0 ± 1.3	6.7 ± .7	61.1 ± 6.5
II		667 ± 14	18.4 ± 4.0	15.9 ± 4.9	98.9 ± 19.2
I	420	818 ± 27	22.8 ± 5.3	12.0 ± 2.4	91.5 ± 19.3
II		813 ± 22	16.0 ± 4.6	18.7 ± 5.2	107.4 ± 22.2
I	490	928 ± 28	48.5 ± 13.6	45.6 ± 13.5	81.1 ± 19.7
II		964 ± 32	129.1 ± 47.9	[1]197.9 ± 44.2	[1]181.1 ± 29.8
I	542	1023 ± 28	73.9 ± 16.6	47.8 ± 13.3	105.7 ± 15.7
II		1080 ± 40	[1]156.0 ± 21.1	[1]149.6 ± 36.7	[1]214.9 ± 23.8
I	574	1084 ± 30	65.1 ± 8.6	28.5 ± 7.3	80.2 ± 11.4
II		1150 ± 44	[1]95.7 ± 10.9	[1]90.1 ± 8.3	[1]233.0 ± 24.2

[1]Significantly greater than Treatment I value ($P < 0.05$; Student's t-test)

CHEMICAL COMPOSITION OF CARCASSES FROM HEREFORD, LIMOUSIN, AND SIMMENTAL CROSSBRED CATTLE AS RELATED TO GROWTH AND MEAT PALATABILITY

John D. Crouse[1] and Michael E. Dikeman

Summary

Nine Hereford x Angus (HxA), nine Simmental x Angus (SxA), and nine Limousin x Angus (LxA) crossbred steers were slaughtered in three equal groups (three from each breed) after 200, 242, and 284 days on feed to evaluate carcass chemical composition differences and their relation to growth and meat palatability.

LxA carcasses were higher in protein and retail product percentages and significantly lower in chemical fat and fat trim percentages than either SxA or HxA carcasses. SxA carcasses were superior to HxA carcasses only in having a lower percentage of fat trim.

SxA steers gained slightly faster in the feedlot than HxA and LxA steers. SxA and LxA steers were equal in weight of retail product produced per day of age and superior to HxA steers. HxA and SxA carcasses were similar in rib eye fat percentages and final quality grades. and they had higher values than LxA carcasses for these characteristics.

Correlation coefficients between carcass chemical composition and palatability traits were low and inconsistent. Correlations between carcass chemical composition and growth rate were also low and inconsistent. In addition, linear regression coefficients indicated little or no association between carcass chemical composition and growth rate or palatability.

Introduction

Several breeds of cattle recently were introduced into North America as germ plasm resources to increase growth rate and proportion of muscle to fat when compared with traditional British beef breeds. Little research has been reported evaluating carcass composition on these newly introduced breeds under beef production and feeding systems used in the United States, and none has involved relationships between carcass composition, growth rate, and palatability traits.

This study was conducted to evaluate carcass composition differences of crossbred steer carcasses representing three breed types and to relate carcass composition to growth rate and meat palatability.

Experimental Procedure

Nine Hereford x Angus (HxA), nine Simmental x Angus (SxA), and nine Limousin x Angus (LxA) steers were obtained by mating Hereford, Simmental, and Limousin bulls to Angus females of a common genetic base. After weaning, the steers were fed a 71% TDN ration (90% dry matter basis). They were slaughtered in three equal groups (three from each breed) after an average of 200, 242, and 284 days on feed.

After carcasses were chilled approximately 24 hr, quality grades and yield grades were determined. The carcasses were transported to Kansas State University, where the right sides were fabricated into trimmed retail cuts leaving 0.3 in fat cover. All cuts were boneless and lean was trimmed to contain approximately 25% fat. Retail product was the total of roasts, steaks, and adjusted lean trim.

Steaks 1.25 in thick were cut from the right wholesale rib at the 12th, 11th, and 10th rib locations. The rib eye muscle from the 12th rib steak was stored at -20°F and later analyzed for intramuscular fat content. The 10th and 11th rib steaks were also frozen; later they were thawed overnight at 38°F, cooked at 350°F in a preheated rotary oven to an internal temperature of 150°F, and allowed to cool at room temperature about 30 min. Six 0.5 in cores were removed from each 11th rib steak and were subjected to the Warner-Bratzler shear test. Cores removed similarly from the 10th rib steak were served to a six-member taste panel who scored them for tenderness, juiciness, flavor, and overall acceptability on a 9-point hedonic scale.

The left side of each carcass was separated into bone and lean plus fat portions (includes kidney and pelvic fat). The lean plus fat portion was thoroughly ground, mixed, and sampled in triplicate for determining carcass percentages of moisture, chemical fat, and protein.

Results And Discussion

Means for percentages of carcass chemical fat, protein, moisture, retail product, and fat trim are presented in Table 1. LxA carcasses had lower percentages of chemical fat and fat trim, and higher percentages of protein, moisture, and retail product than SxA or HxA carcasses. Chemical fat, protein, moisture and retail product percentages of SxA were not different from those of HxA carcasses. However, SxA carcasses had less fat trim when fabricated into retail cuts.

There were no carcass composition differences between the first and second slaughter groups. However, carcasses in the third slaughter group had more chemical and trimmable fat, and less protein, moisture, and retail product than either of the other groups. One would have expected steers in the second slaughter group, on feed 42 days longer than those in the first group, to have more fat and less lean than those in the first group. The study revealed no significant breed x slaughter group interactions for traits studied.

Differences among breeds in average daily gain were not considered large enough to be of importance with the number of cattle sampled (Table 2). SxA and LxA steers were equal in pounds of retail product produced per day of age, and both were superior to HxA steers. Although LxA carcasses had higher percentages of retail product than SxA, they were not superior in retail product per day of age because they had lighter slaughter weights at similar ages.

Table 1.—Least squares means

Item	Carcass chemical fat (%)	Carcass protein (%)	Carcass moisture (%)	Retail product (%)	Fat trim (%)	ADG (lb)	Final weight (lb)	Quality grade[1]	Rib eye fat (%)	Retail product per day of age (lb)
	CARCASS COMPOSITION DATA					GROWTH AND CARCASS TRAITS				
Breed:										
HxA	38.51	13.27	47.15	65.07	23.19	2.6	1075	9.67	6.36	0.90
SxA	35.89	13.95	49.10	67.32	20.05	2.8	1145	9.55	6.27	.99
LxA	31.16	15.35	52.51	72.18	15.63	2.6	1046	8.33	4.10	1.01
Average	35.19	14.19	49.59	68.19	19.62	2.7	1088	9.18	5.58	.97
Slaughter group:										
1	33.69	14.58	51.11	69.02	18.03	2.8	1022	9.00	4.49	.99
2	33.31	14.70	50.50	69.80	17.98	2.6	1048	9.11	5.95	.97
3	38.57	13.29	47.15	65.74	22.87	2.5	1093	9.44	6.30	.97

[1]High Good = 9, low choice = 10, etcetera.

Continued at bottom of next page.

[1]John D. Crouse is a meat scientist at MARC.

EVALUATION OF TRAITS IN THE USDA YIELD GRADE EQUATION FOR PREDICTING BEEF CARCASS CUTABILITY IN BREED GROUPS DIFFERING IN GROWTH AND FATTENING CHARACTERISTICS

John D. Crouse[1]

Summary

Carcasses of 786 steers derived from crosses of Hereford or Angus cows bred to Hereford, Angus, Charolais, Limousin, Simmental, South Devon, and Jersey sires were fabricated into closely trimmed, semi-boneless retail cuts to study relationships among independent variables in the USDA yield grade equation in breed groups that differ in growth and fattening characteristics.

Simple correlations indicate carcass weight was a good predictor of cutability within a breed group but a poor indicator over all breed groups. Rib eye area had the lowest predictive value of the four variables studied. Rib eye area may be more useful in populations of similar weight than in those varying widely in weight. Fat thickness at the 12th rib was the most useful predictor of cutability and is about equally useful within or over all breed groups. Percentage of kidney and pelvic fat, though lower in predictive value than 12th rib fat thickness, was useful within or over breed groups. Partial regression coefficients computed within each breed group were relatively similar though there were significant differences in intercept values for the different breed groups. Use of a single prediction equation for all breed groups would rank animals well within a breed group.

[1]John D. Crouse is a meat scientist at MARC.

Introduction

Accurate, reliable predictors of carcass cutability are needed by the beef cattle industry for marketing, progeny testing, and research programs. To have widespread application, the procedure must be rapid, inexpensive, and applicable under diverse management conditions and must lend itself to a broad base of genetic types.

Numerous equations for estimating percentage of carcass cutability have been developed independently on carcasses derived from British beef, dairy, and Brahman breeding. The present USDA (1965) yield grade equation for estimating percentage closely trimmed, boneless round, loin, rib, and chuck was derived from the regression equation by Murhpey *et al.* (1960) and has been tested on independent populations of beef carcasses. Although the relationships in the independent populations differed from that of the original population, the variables used in the yield grade equation appear to be the most acceptable among those reported when accuracy, rapidity, and expense are considered.

The objective of this investigation was to study the relationships among variables found in the multiple regression equation by Murphey *et al.* (1960) when applied to carcass beef derived from some of the newly introduced breeds being used in the United States.

Data for this study were obtained from 786 steer calves born in 1970 and 1971 as part of a cattle germ plasm evaluation program. Hereford and Angus cows were mated to Hereford, Angus, Charolais, Limousin, Simmental, South Devon, and Jersey sires by artificial insemination. A range in length of feeding period was provided by stratifying calves in sire breed groups by age and assigning them to one of three slaughter groups each year (215, 243, and 271 days postweaning for 1970, and 200, 242, and 284 days postweaning for 1971 calves). Therefore, animals within sire breed groups varied slightly in age and in time on feed, but average age and time on feed was similar between breed groups.

Steers were slaughtered at a commercial packing plant. Yield and quality

Continued on next page.

Continued.

Table 2.—Least squares means for rib eye palatability traits

Item	Warner-Bratzler shear, (lb)	Taste panel tenderness[1]	Taste panel juiciness[1]	Taste panel flavor[1]
Breed:				
HxA	6.7	7.56	7.24	7.46
SxA	8.0	7.31	7.49	7.59
LxA	8.7	6.83	6.79	7.59
Average	7.8	7.23	7.17	7.55
Slaughter group:				
1	7.5	7.33	6.86	7.48
2	6.8	7.50	7.28	7.58
3	9.1	6.88	7.38	7.59

[1]Score of 1 = extremely undesirable, 9 = extremely desirable.

HxA and SxA carcasses had similar quality grades and percentages of rib eye fat even though SxA carcasses had less fat trim. LxA carcasses were lower in quality grade and had less rib eye fat as expected because they had less total carcass fat.

Neither breed nor slaughter group significantly affected Warner-Bratzler shear force or taste panel palatability scores (Table 3). Even though LxA carcasses graded lower and had less rib eye fat than HxA or SxA, LxA shear values and taste panel scores were not different form SxA and HxA values.

Correlations indicated that average daily gain (ADG) was not associated with protein, moisture, or fat composition of the carcass. Additionally, chemical composition of the carcass was not correlated with taste panel scores or Warner-Bratzler shear values. However, fatter carcasses and those with higher percentages of rib eye fat tended to have higher taste panel juiciness and overall acceptability scores (correlations ranged from 0.20 to 0.35). Results in our study indicate that carcass fat and rib eye fat are unsatisfactory indicators of palatability.

Linear regression indicated increased carcass protein percentages were not associated with higher feedlot ADG. This fact is supported by means for protein and ADG for the three breed types. Each 1% increase in carcass protein was associated with 49 lb lower live weight. Retail product percentage increased 3.06% for each 1% increase in carcass protein.

Rib eye chemical fat increased 0.27% for each 1% increase in carcass chemical fat. The regression coefficients for taste panel flavor, juiciness, and tenderness scores on carcass chemical fat were 0, 0.04 and 0.01, respectively, indicating that increased carcass fatness did not result in any measurable increase in palatability.

grade factors were determined 24 hr postmortem by a consensus opinion of three appraisers. The right side of each carcass was processed into retail trimmed cuts leaving no more than a 0.3 in fat cover. Dorsal and transverse spinous processes remained in the short loin cuts, and dorsal spinous processes and rib bones remained in the rib cuts. All other cuts were entirely boneless.

For purpose of analysis and interpretation, the seven sire breed groups were regrouped into four as follows: (1) Hereford, Angus, and their reciprocal crosses = HA; (2) Charolais, Limousin, and Simmental crosses = CLS; (3) South Devon crosses = SD; (4) Jersey crosses = J. Most of the cutability equations developed to date have used cattle of British beef breed types. Charolais, Limousin, and Simmental crosses represent the newly introduced Continental breeds and have a rapid growth rate and thin subcutaneous fat layer compared with that of the traditional British beef breeds. South Devon crosses appeared to have growth and fattening characteristics intermediate between the British beef breeds and Continental breeds. Jersey crosses had the lowest growth rate of breeds evaluated and a total fat content similar to that of the British beef breeds.

Results And Discussion

Variation in traits in this study is greater than would be expected within cattle of a given breed fed for a constant time or to a relatively constant condition. The range in maturity and quality grades is not, however, as large as that represented in the study of Murphey *et al.* (1960) from which the USDA yield grades were developed.

The distribution of sample populations is important in interpreting measures of relationship between traits. Relationships observed can be influenced by the fact that various subpopulations may be included in the sample, as is the case for sire breed groups here. In this situation, relationships among group means as well as those within a group influence correlations and regressions where the sample is analyzed as one population. These considerations should be kept in mind when comparing the correlations or regressions obtained by various groupings in this study and their comparison to other studies.

Correlations among carcass traits are shown in Table 1. Correlations above the diagonal were calculated over all sire breed groups and include the effects of sire breed group means. Correlations below the diagonal were calculated within sire breed group, breed of dam, and year. Correlations between percentage cutability with carcass traits did not differ among the sire breed groups. Results from the overall breed group analysis would be appropriate when drawing inference to a population of carcasses consisting of a number of breeds or breed crosses differing significantly in weight and body composition as observed in these data. Results from the pooled within-breed group analysis approximate the average correlation between traits for carcasses derived from a given breed or breed cross.

Table 1.—Correlations among carcass traits[1]

Carcass traits	Carcass weight	Rib eye area	Adj. fat thick.	K and P fat (%)	Cutability (%)
Carcass weight	0	0.59	0.26	0.01	-0.07
Rib eye area	.50	. . .	- .28	- .08	.47
Fat thickness	.50	- .04	. . .	.02	- .76
K and P fat ___%	.25	.08	.18	. . .	- .37
Cutability, ___%	- .42	.18	- .73	- .40	. . .

[1]Correlations above the diagonal were calculated over all sire breed groups, within breed of dam, and year subclasses. Correlations below the diagonal were calculated within sire breed group, breed of dam, and year subclasses.

A correlation of -0.42 was observed between carcass weight and percentage cutability on a within-breed group basis. On an overall breed group basis, this correlation was reduced to -0.07. In this study, CLS crosses had heavier but trimmer carcasses than the other breed groups and had the highest percentage cutability. Breed group means for carcass weight were positively associated with percentage cutability. The net result of a strong negative relationship within breed groups and a strong positive relationship between breed group means is the low negative overall correlation (-0.07) where breed group was ignored. This result suggests that carcass weight is a useful predictor of cutability within breed groups but not in populations representing a wide range of breed types.

The correlation between cutability and rib eye muscle area was much larger (0.47) over all sire breed groups than it was within sire breed groups (0.18). There was a strong positive relationship between the breed group means for cutability and rib eye muscle area. This strong relationship indicates that rib eye muscle area may be particularly useful in prediction equations to partly account for variability in cutability that is associated with breed group differences.

The individual trait most highly correlated with percentage cutability was fat thickness (-0.76) at the 12th rib. This relationship was approximately the same whether considered over all sire breed groups or pooled within groups. The magnitude of the correlation between fat thickness and percentage cutability and the homogeneity of the relationships over all or within breed groups indicate fat thickness would be a valuable predictor of cutability in a population of carcasses regardless of genetic origin.

The correlations between percentage of kidney and pelvic fat (K and P fat) and cutability were -0.37 on an overall basis and -0.40 on a pooled within-breed group basis. Breed group means for cutability and percentage of K and P fat were not correlated. Although the correlation between cutability and percentage of K and P fat is only moderate, this measure of fatness should be a useful predictor of cutability within breeds or over mixed breed population.

Regression equations developed (Table 2) overestimated HA, SD, and J breed group means and underestimated the CLS means. Equation 1 has hot carcass weight, rib eye area, adjusted fat thickness, and percentage K and P fat. Equation 2 omits carcass weight. The poorest fit was for Jersey crosses. Equation 2, with carcass weight deleted, had less bias associated with breed group means than equation 1. The consistently lower values when the Murphey equation was used can possibly be accounted for by differences in cutting procedure, differences in the trait means for the populations evaluated, and difference in relative size of the regression coefficients. The Murphey equation did a good job of ranking within groups as evidenced by correlations between actual and estimated cutability within breed groups of 0.82 for HA, 0.78 for CLS, 0.85 for SD, and 0.73 for J.

Table 2.—Comparison of actual and predicted cutability by sire breed groups using various equations

Bread group	Actual cutability (%)	Prediction equation 1 (%)	2 (%)	Murphey (%)
HA	51.0	51.6	51.6	48.8
CLS	55.7	55.5	55.6	51.0
SD	52.1	52.6	52.6	49.4
J	50.7	51.5	51.4	49.1

ESTIMATION OF RETAIL PRODUCT OF CARCASS BEEF

John D. Crouse[1]

Summary

Carcasses from 1,121 steers (progeny of Hereford or Angus cows mated to Hereford, Angus, Charolais, Simmental, Limousin, South Devon, or Jersey sires by artificial insemination) were examined to develop equations to estimate percentage of retail product. The independent variables chosen and resultant accuracy of the equations developed, reflect different kinds of measurements that could be used to predict cutability over a wide range of data collection conditions.

Of 18 traits readily obtained in the cooler, adjusted fat thickness, rib eye area, estimated kidney and pelvic fat, hot carcass weight, and marbling score were the most important in predicting percentage of retail product. A multiple regession equation involving these five independent variables accounted for 79.2% of the variation in percentage of retail product.

Results showed that adequate alternatives other than complete cutout of carcasses do exist to determine yields of retail product. Reasonably precise estimates of percentage or retail product can be made based on prediction equations involving independent variables measured on carcasses in the cooler alone or in combination with partial cutout data. These estimates should be especially useful when a large number of carcasses are to be evaluated.

Introduction

Retail product yield is a useful measure of the saleable portion of carcass beef. Time and resources are often not available to obtain actual retail yields. Thus, reliable estimates of retail product yield are needed in marketing, progeny testing, and in research programs.

Numerous equations for estimating percentage of carcass cutability have been developed on carcasses derived from British beef, dairy, and Brahman breeding. The present USDA (1965) yield grade equation estimates percentage of closely trimmed, boneless round, loin, rib, and chuck (Murphey *et al.*, 1960). In this regression equation, independent variables are those that can be measured rapidly with minimal expense on carcasses in the cooler. When tested on independent populations of carcass beef, it has been found to be useful on carcasses derived from animals having the same growth and fattening patterns.

The purpose of this study was to develop prediction equations to estimate retail product for carcass beef derived from steers varying in rate and composition of growth. Predictors chosen reflect different situations relative to resources available to make required observations.

Data were obtained from 1,121 steer calves born in 1970, 1971, and 1972 as part of a cattle germ plasm evaluation program for beef production. Hereford and Angus cows were mated to Hereford, Angus, Charolais, Limousin, Simmental, South Devon, and Jersey sires by artificial insemination. Calves were stratified within sire breed groups by age and assigned to one of three slaughter groups each year (215, 243, and 271 days postweaning for 1970; 200, 242, and 284 days for 1971; and 220, 245, and 283 for 1972).

Yield grade and quality grade factors and linear measurements were determined 24 hr postmortem. Muscling was scored from 1 (extremely thick) to 10 (extremely thin). Carcass length, hindquarter length, round length, round thickness, chuck thickness, and chest depth were measured.

The right side of each carcass was taken to Kansas State University and processed into retail cuts trimmed to no more than 0.3 in fat cover. Dorsal and transverse spinous processes remained in the short loin cuts, and dorsal spinous processes and rib bones remained in the rib roast. All other retail cuts were made entirely boneless. Kidney and pelvic (K and P) fat of the right side was weighed and expressed as a percentage of the right side weight. Percentage of retail product was determined by dividing the weight of the trimmed retail yield from the round, loin, rib, and chuck plus lean trim from the entire side by the sum of individual weights of all side componets. Percentages of rib retail product, rib fat trim, round retail product, and round fat trim were expressed relative to weights of their respective wholesale cuts.

Results And Discussion

Regression equations with standard errors and coefficients of determination for predicting percentage of retail product are given in Table 1. An R^2 is the variation accounted for by a prediction equation divided by the total variation. It is, therefore, a measure of the accuracy of the prediciton equation. Equations are presented on an overall breed of sire subclass basis and a pooled within-breed of sire subclass basis. Inferences from the overall analysis would be applicable to a population of carcasses similar to those of the breed groups sampled in the present study. Results from the pooled within analysis represent the average response within the seven sire breed groups. Differences in standard errors and coefficients of determination of equations developed by the two subclass basis are largely due to the reduction in variation associated with breed group means. Independent variables presented are those that were found to be the most important by stepwise regression procedures and to be of practical usefulness in various resource situations where observations may be made in the cooler, on partial cutout of the carcass, or on chemical analysis of the 9-10-11th rib sections. Additional independent variables were significant and made some improvement in the R^2, but these contributions were negligible and of little practical consequence.

Equations 1 through 4 (over all subclasses) and equations 9 through 12 (within subclasses) involve independent variables observed in the cooler, which can be obtained with rapidity and with modest expense. These equations involve traits found in the yield grade equation with the addition of marbling score. Equations 1, 9, and 11 omit hot carcass weight. The usefulness of hot carcass weight in an equation representing all breed groups is somewhat questionable. This is due to the negative effect heavier carcasses have on predicted percentage of retail product.

Measurements of length and thickness of the carcass or components of the carcass made no practical contribution to the R^2 when marbling score was included in the equation. Subjective measurements of carcass muscling were important. However, if marbling score was included in the equation, then the contribution of muscling score was minimal.

Preliminary correlation analysis of closely trimmed wholesale cuts with percentage retail product indicated that the wholesale round and the rib cuts were the best indicator of closely trimmed carcass retail products. Consequently, regression equations were generated utilizing independent variables derived from cooler observations and partial cutout of the round and rib. Equations 5 and 13, involving percentage of trimmed round and percentage of retail product of the round, respectively, incorporated adjusted fat thickness and the actual percentage of K and P fat. Variation in actual K and P fat was more highly associated with variation in retail product than estimated K and P fat as shown by the results of the correlation analysis. Processing the round would require removel of K and P fat from the

Continued at bottom of next page.

[1]John D. Crouse is a meat scientist at MARC.

RELATIONSHIP OF SELECTED BEEF CARCASS TRAITS WITH MEAT PALATABILITY

John D. Crouse[1]

Summary

Relationships among selected carcass traits and cooked meat palatability were studied on 240 carcasses obtained from steers of different biological types produced under a wide range of feeding regimens. Breed type of steer or feeding regimen had little or no effect on correlations among taste panel (TP) scores for tenderness, juiciness, flavor, and general acceptability. Treatments also had little effect on correlations of conformation, lean color, lean texture, and final maturity with TP observations. Late maturing breeds of steers and steers fed on low energy regimens were rated more youthful than early maturing breeds of steers and steers fed on high energy regimens. Marbling, percentage of longissimus muscle (LM) fat, quality grade, and adjusted fat thickness independently accounted for 2 to 3% of the variation in TP tenderness and 6 to 8% of the variation in TP acceptability.

[1]John D. Crouse is a meat scientist at MARC.

Introduction

The USDA has recently implemented three major changes in standards for quality grading carcass beef (USDA, 1976). First, conformation was eliminated in determining final quality grades (QG). Second, marbling requirements for the Good grade were narrowed to include only carcasses with a slight amount of marbling. Third, minimum marbling requirements for an A maturity carcass in

Continued on next page.

Continued.

hindquarter. Therefore, actual K and P fat could be determined and errors due to estimation would be removed. Equation 5 and 13 accounted for 86.1 and 79.1% of the variation in percentage of retail product on an overall breeds of sire and on a pooled within breeds of sire subclass basis.

Equations 6 and 14 (involving adjusted fat thickness (FT), estimated percentage of K and P fat, marbling score, and percentage of rib fat trim) were not as accurate or reliable as equations 5 and 13 in which partial cutout of the round was used. However, equation 6 did account for 80.2% of the variation in percentage of retail product, and observations were obtained with rapidity and minimal resources requiring less labor.

Ether extract of the 9-10-11th rib, in addition to adjusted FT, longissimus area (LA), and percentage of K and P fat, was used in equations 7 and 15 and accounted for 85.5% of the variation in percentage of retail product over all breeds of sire. Equation 7 was a significant improvement over equation 1, increasing the R^2 by 10.1% and reducing the standard error by 23.8%.

Equations 8 and 16 (involving independent variables: adjusted FT, actual percentage of K and P fat, percentage of round retail product, and percentage of ether extract of the 9-10-11th rib) provided the best fit. The two equations accounted for 89.5 and 84.0% of the variation in percentage of retail product overall and pooled within-breed of sire subclasses, respectively. Standard errors of the respective equations were 1.44 and 1.40%. Equation 8 should provide a useful alternative to complete carcass cutout for determining retail product where a small error in estimation can be tolerated.

The results of this study indicate that adequate alternatives exist to complete carcass cutout to obtain retail product. The accuracy and reliability of these alternatives are related to the amount of time and resources provided for labor and instrumentation required to make carcass observations. However, estimates adequate for many purposes, namely, group averages involving a large number of observations, can be made with minimal input. The level of precision required of an experiment in which retail product is to be observed can be predetermined. Experimental design and a method of making this observation with minimum inputs at the required level of precision can be selected.

Table 1.—Regression equations for predicting percentage of retail product

Equation number	Subclass basis	N	SE	R^2	Intercept	Adj. FT (in)	Longissimus area (in^2)	K & P K & P fat (%)	Carcass weight (lb)	Marbling score[1]	Actual K & P fat (%)	Trimmed round (%)	Round RP (%[2])	Rib fat trim (%)	Rib ether extract (%)
						Partial regression coefficients									
1	Overall[3]	1121	2.23	0.754	74.9	−17.8	0.55	−1.47	0	0	0	0	0	0	0
2		1121	2.18	.765	75.6	−16.1	.86	−1.42	.008	...	...	...	...	...	...
3		1121	2.11	.780	76.1	−16.5	.56	−1.23	...	−.234	...	...	...	...	...
4		1121	2.05	.792	77.0	−14.7	.89	−1.17	−.009	−.240	...	...	...	...	...
5		1121	1.68	.861	1.9	−8.2	...	...	...	...	−.78	.89	.70	...	...
6		1121	2.00	.802	85.1	−9.3	...	−1.15	...	−.219	...	...	...	−.403	...
7		334	1.70	.855	87.0	−8.0	.33	−.70	...	...	...	...	...	...	−.399
8		334	1.44	.895	37.4	−5.7	...	...	...	...	−.911	...	.65	...	−.296
9	Within[4]	1121	2.08	.655	75.8	−17.2	.36	−1.18	...	...	...	...	...	...	...
10		1121	2.02	.673	77.2	−14.6	.67	−1.06	−.010	...	...	...	...	...	...
11		1121	1.99	.687	76.8	−16.1	.42	−1.07	...	−.215	...	...	...	...	...
12		1121	1.92	.705	78.3	−13.5	.72	−.95	−.010	−.215	...	...	...	...	...
13		1121	1.61	.791	34.2	−14.0	...	...	...	...	−1.20	.53	.44	...	...
14		1121	1.84	.730	83.3	−9.4	...	−.85	...	−.186	...	...	...	−.363	...
15		334	1.65	.781	86.2	−8.5	.34	−.68	...	...	...	...	...	...	−.377
16		334	1.40	.840	35.3	−5.6	...	...	...	...	−.85	...	.66	...	−.269

[1]Scored small− = 10, small⁰ = 11, small+ = 12, et cetera.
[2]Percentage retail product of the round.
[3]Regression equations were computed over all breed of sire subclasses.
[4]Regression equations were based on a pooled within breeds of sire subclass sums of squares and cross products matrix.

Table 1.—Simple correlations among selected carcass traits and palatability traits

Trait no.	Trait	1	2	3	4	5	6	7	8	9
1	Final maturity	---	0.25	0.26	0.22	0.02	0.07	0.08	0.04	0.04
2	Marbling	---	---	.96	.66	.22	.24	.32	.33	.15
3	Quality grade	---	---	---	.66	.22	.24	.33	.34	.14
4	Fat thickness	---	---	---	---	.27	.29	.38	.38	.12
5	Taste panel tenderness	---	---	---	---	---	.32	.55	.78	.63
6	Taste panel juiciness	---	---	---	---	---	---	.64	.66	.05
7	Taste panel flavor	---	---	---	---	---	---	---	.84	.23
8	Taste panel acceptability	---	---	---	---	---	---	---	---	.39
9	Warner-Bratzler shear	---	---	---	---	---	---	---	---	---

the Prime, Choice, Good, and Standard grade no longer increases with increasing maturity. These changes were the result of research that has shown that maturity, within youthful carcasses, and conformation have little relationship to palatability.

Low positive correlations between marbling score or LM lipid content with TP acceptability scores have been reported for steaks from youthful carcasses. Results from a number of studies have indicated significant relationships between maturity and TP palatability characteristics when evaluated over a range of youthful to mature carcasses. Berry *et al.* (1974) observed significant correlations between TP palatability scores and maturity when evaluated over the full range of maturity groups. However, these correlations were observed to be low and nonsignificant when evaluated within the A maturity group.

Because more than 97% of the "fed" beef is within A maturity, the effect of maturity within A maturity on palatability of steak and roast meat is of most interest. In most previous studies, carcasses from animals with relatively similar growth rates and fattening characteristics typical of domestic beef breeds finished on medium to high energy density diets have been sampled to determine the efficiency of carcass criteria in estimating palatability. In the present study, relationships of carcass quality indicating criteria with palatability and how these relationships were affected by breed groups and nutritional environment were examined. Observations were made on carcasses obtained from steers that varied greatly in growth and fattening characteristics and produced under a wide range of feeding regimens.

Experimental Design

The experimental design ensured variation in carcass traits such as maturity (within the A maturity classification) and carcass composition with relatively low covariance among these traits. This variation allowed an evaluation of independent as well as multiple effects of maturity, marbling, and other traits on palatability. Carcasses from 120 large, late maturing (Chianina, Charolais, Brown Swiss, and Limousin crosses) and 120 small, early maturing (Hereford, Angus, and Red Poll crosses) steers were evaluated. At approximately 250 days of age, steers were assigned to one of five feeding regimens ranging from pasture feeding to an 80% concentrate diet. Serial slaughter techniques were used. Steers were killed at about 90 and 105% of the approximate mature weights for females of these biological types (small: 1,050 lb; large: 1,200 lb). An additional slaughter group was slaughtered at the beginning of the higher concentrate feeding periods in regimens A, B, and D.

All steers were slaughtered by a commercial packer. Carcasses were evaluated and quality graded by USDA standards after a 24-hr chill at 2°F.

Correlations

Correlations among selected carcass traits are presented in Table 1. Preliminary analyses indicate that breed type of steer and feeding regimen had no effect on magnitude of correlations. The very low correlation between final maturity and TP traits in these A maturity carcasses agrees with previous research and supports recent modifications of maturity in the USDA grade standards.

Carcass traits most highly associated with taste panel traits were measures of fatness. A low positive correlation between marbling and TP traits was also observed; however, the amount of variability in TP tenderness accounted for by marbling (3%) was low. Interestingly, fat thickness (FT) was as highly correlated to TP traits as measures of marbling. This relationship was not appreciably affected by treatment subclass means. The covariance between marbling and FT ($r = 0.58$) would partly account for the relation of FT to TP traits. Partial correlations between FT and TP items holding marbling constant (Table 2) were low but real for TP flavor and acceptability. Partial correlations between marbling and TP items holding FT constant were lower than the former correlations. These observations indicate that FT and marbling would be of similar value in estimating TP panel evaluations of organoleptic traits.

Holding maturity constant had little effect on correlations between marbling and TP traits. However, variation in marbling appears to be slightly less associated with TP traits at a constant time on feed than when time on feed is allowed to vary within subclass treatments.

Simple regressions of TP tenderness and TP acceptability on marbling and fat thickness are shown in Table 2. Regression curves of TP traits on carcass traits were flat. A change of 30° in marbling (scored 0 = devoid to 30 = very abundant) was required to make a one-unit increase in TP tenderness values. Fat thickness was required to increase by 1 in to make a similar change. Marbling, QG, and FT independently accounted for 2 to

Table 2.—Regression equations for taste panel tenderness and acceptability

Dependent variable	R^2	SE	Intercept	Carcass traits and coefficients: Marbling	Fat thickness
TP tenderness	0.03	0.75	4.60	0.033	
	.03	.75	4.75	.039	
TP acceptability	.06	.51	4.68		.036
	.08	.50	4.65		.042

Table 3.—Frequency distribution of taste panel tenderness scores

Marbling score	Number of samples	3 or greater No.	3 or greater %	4 or greater No.	4 or greater %	5 or greater No.	5 or greater %	6 or greater No.	6 or greater %
P devoid	17	17	100	13	76	6	35	1	6
Traces	47	46	98	37	79	20	43	4	9
Slight	83	83	100	72	87	41	49	4	5
Small	54	53	98	50	93	27	50	4	7
Modest	26	26	100	26	100	19	73	1	4
Moderate	8	8	100	7	88	5	63	2	25
≤ S abundant	5	5	100	5	100	4	80	0	0
Number/score			28		88		106		16

Taste panel tenderness scores are grouped under the column heads 3 or greater, 4 or greater, 5 or greater, 6 or greater.

Continued at bottom of next page.

METHANE AND PROTEIN FROM BEEF CATTLE MANURE

Andrew G. Hashimoto,[1] Yud-Ren Chen, Vincent H. Varel, and Ronald L. Prior

Introduction

Dwindling supplies of conventional fossil fuels have prompted renewed interest in recovering energy through the bioconversion of waste organic materials. The large quantities of manure produced in confinement feedlots and the need to manage this manure effectively make feedlots a logical choice for assessing the feasibility of recovering methane and protein through anaerobic fermentation.

Research at MARC is designed to determine the technical and economic feasibility of recovering methane and protein from beef cattle manure.
Sepcific objectives are to:

(1) Develop design criteria for optimum production of methane and protein through anaerobic fermentation of beef cattle manure,
(2) Develop efficient methods to recover high protein biomass from the fermented residue,
(3) Evaluate the nutritional value of the biomass as a livestock feed,
(4) Determine the capital and operational costs and energy, manpower, and safety requirements for methane fermentation systems associated with livestock operations.

This project was initiated in 1976 and is jointly funded by the U.S. Department of Agriculture, Agricultural Research Service, and the U.S. Department of Energy through the Solar Energy Research Institute.

Anaerobic Fermentation

MICROBIOLOGY. Anaerobic fermentation is a biological process in which organic matter decomposes without oxygen to yield methane. The phenomenon occurs naturally when organic material remains without oxygen under conditions amenable to microbial processes. Such conditions prevail in many natural environments ranging from pond sediments to the gastrointestinal tract of animals. Use of the methanogenic process for generating energy from organic residues requires an understanding of the mechanisms involved and the factors affecting these mechanisms.

BIODEGRADABILITY. Because anaerobic fermentation is a biological process, the biodegradability of the material being fermented affects the product yield. We found that the roughage content of cattle rations affects the biodegradability of the manure.

Manure from cattle fed a ration of 91% corn silage and 40% corn silage produced 80% and 60%, respectively, the amount of methane produced by manure from cattle fed 7% corn silage. We have also shown that the age of manure and amount of such foreign material as dirt and bedding can reduce the methane yield by 30 to 50%. Thus, we estimated that the maximum amount of methane that can be produced from fresh manure from finishing cattle is 5.5 ft of methane/pound of organic matter. Old manure or manure from cattle fed high roughage rations would produce about one-half to two-thirds this amount.

Methane Production Rate

Although our research on biodegradability shows the maximum amount of methane that can be produced from cattle manure, it is not practical to extract the maximum amount because of the long fermentation time and larger fermentor volume required. Thus, it is important for researchers to predict the methane production rate under different fermentation conditions. We have developed an equation that predicts the methane production rate (in cubic feet of methane/cubic feet of fermentor/day) based on the biodegradability and concentration of manure being fermented, the fermentation time, and two kinetic parameters. Using this equation, we found that the highest methane production rate occurrs at 60° C. Rates at 30, 35, 40, 45, 50, 55, and 65° were 42, 52, 64, 78, 92, 89, and 52% of the rate at 60°. We also found that methane production is inhibited when manure concentration exceeds 5 lb of organic matter/cubic feet. Thus, to achieve high methane production rates, while maintaining stable fermentation, we recommend operating fermentors between 50 to 55°, manure loading rate of 1 lb of organic matter/cubic feet of fermentor/day, and retention time of 5 days.

Energy Requirement

Our studies have shown that the major energy requirement for operating fermentors between 50 to 55° C was for heating the fermentor. About 37% of the energy produced by the system was needed for heating. This amount was reduced to 20% when half of the effluent heat was recovered to help heat the manure entering the fermentor. The next main energy user was for mixing the manure and fermentor contents. Mixing amounted to 7% of the total energy production when the mixers were run contінously. Mixing energy can be reduced substantially when intermittent mixing is used. Continuous mixing produces, at most, only a 10% higher methane production rate than mixing 2 hr/day. Energy required to pump the manure into and out of the fermentor accounted for about 4% of the total energy produced. Thus, the energy required to operate the fermentation systems accounts for about 30 to 50% of the energy produced.

Feeding Fermentor Effluent

Using the fermentor effluent as a feed ingredient for livestock appears to have merit, although some technical

Continued at bottom of next page.

[1]Andrew G. Hashimoto is a research leader (Agricultural Engineering) at MARC.

Continued.

3% of the variation in TP tenderness and 6 to 8% of the variation in TP acceptability.

Frequency Distributions

Table 3 gives frequency distribtuions of TP tenderness scores and acceptability scores for each marbling score. The percentage of samples with or above a given level of desirability for each marbling score is shown. At a level of TP satisfaction for tenderness of three or over, the probability of attaining this level of satisfaction would be 100% at the practically devoid level of marbling. However, the probability of attaining a higher level of satisfaction, say 5, would only be 35% at the practically devoid level of marbling. To attain a TP tenderness score of four or greater with an 87% probability, slight amounts of marbling would have been required.

In the present study, the relationship existed between carcass quality, indicating criteria and TP traits were very low. For example, marbling accounted for only 6% of the variation in TP acceptability, and a thirtyfold increase in marbling would be required to yield a one-unit change in TP responses.

COOPERATIVE PROJECT ON THE WEAK CALF SYNDROME

William G. Kvasnicka[1]

Introduction

The "Weak Calf Syndrome" has been gaining wide recognition throughout the northwest and Rocky Mountain regions. The specific syndrome was first noted as possibly being caused by a new entity by Dr. Jack Ward in the Bitterroot Valley of Montana after Dr. Ward was unable to relate the observations of necropsied specimens with that of any known published reports. The actual orgin of the disease responsible for the specific syndrome noted in the area is not known and may have had its orgin elsewhere. However, interest in the problem is increasing in view of the apparent recognition of the disease and acknowledgment of its presence in many different areas.

The problem is particulary devastating when experienced within a herd for the first time, as losses range from 25% to as high as 75% of the calf crop. The initial recognition has been an increase in the abortion rate followed by the calves' inability to rise at birth. The degree of weakness has varied from animal to animal. Many of the calves will be polyarthritic and most die soon after. A few animals are able to survive when immune therapy, blood transfusion, electrolyte solutions, or other fluids are administered. A large number of the animals that survive progress poorly, attaining weight gains of one-half that of their normal counterparts.

Gross Pathology

1. Aborted fetuses: Edema of subcutaneous and interstitial tissues throughout the body; port-wine colored fluid in the pleural and peritonal cavities, and hemorrhagic lesions in the subcutaneous tissues.
2. Calves delivered at term and those dying after delivery: Subcutaneous edema, hemorrhages in the anterior neck and masseter muscles and in the muscles of the extremeties. Bloody synovial fluid with fibrin. Petechial hemorrhages in the third eyelid, sclera, conjunctiva, ventral surface of the tongue, esophagus, trachea, and frequently in the thymus. Enlarged and edematous suprascapular and prefemmoral lymph nodes. Mild to severe gastroenteritis associated often with enlarged mesenteric nodes. Striking reddish muzzle turning somewhat leathery within a few days, etc.

Neonatal calf losses observed at MARC similar to those occurring in the northwest were first observed near the end of calving 1975. Losses in the 1976 calving season reached levels of 10% of the calves born to heifers;1977 losses were similar to 1976. Dr. Arlan McClurkin, research veterinarian, National Animal Disease Center, has observed the losses here and has conducted extensive work attempting to isolate infectious agents.

Extensive research is being conducted by groups at Idaho State, Montana State, and Montana University. In general, the research being pursued is to search for viral agents that will reproduce the disease, to develop a diagnostic test to identify affected calves that do survive, vaccine development, and the relation of the diseases to cold-weather stress and/or nutrition.

US MARC Cooperative Research Project

Background. Neonatal calf disease with signs and lesions similar to those decribed for the Weak Calf Syndrome are now recognized as a serious problem in Nebraska as well as in most other states of the Old West Region. One of the herds in which it is a problem of considerable severity is the one at the U.S. Meat Animal Research Center (MARC). The problem at MARC has recurred annually for several years in first calf heifers. This herd will be a reliable source of materials with which to search for an infectious agent.

The facilities at the University of Nebraska are excellent for carrying out a search for a hard-to isolate infectious agent. Facilities for obtaining and holding gnotobiotic calves are unmatched in this country, and strict isolation facilities are abundant. There are also new, well-equipped research laboratories for virology, bacteriology, pathology, biochemistry, immunology, and electron microscopy; excellent diagnostic laboratories at Lincoln and North Platte; and a smaller diagnostic laboratory at Scottsbluff.

There are excellent facilities and personnel at MARC for handling and collecting materials from sick animals and for doing preliminary laboratory procedures. The record-keeping at MARC is a real asset in obtaining accurate histories for dams of weak calves.

[1]William G. Kvasnicka is the herd health veterinarian at MARC.

Continued on next page.

Continued.

problems must be solved. Dried centrifuged effluent can be fed at a level up to 10% of the dietary dry matter and not change the use of the diet components by the animal. Disadvantages of feeding dried centrifuge effluent are that more than one-half of the nitrogen is not captured by centrifugation, and capital and energy costs needed to install and operate the centrifuge and drying systems are high. Eliminating the drying process would retain more nitrogen, but storing the wet centrifuged solids would be a problem. Mixing the total fermentor effluent into a ration has the advantage of using most of the nutrients. However, the amount of moisture in the effluent limits the amount of effluent that can be mixed into a total ration. The major effects of feeding fermentor effluent have been a decreased apparent digestibility of dry matter, nitrogen, ash, and gross energy in sheep and decreased total ruminal fatty acid concentrations before and after feeding in steers.

Economics

Economic studies show that methane can be economically produced at moderate plant sizes (between 3 to 7 tons of dry matter/day) when farmer-constructed and operated systems are used. Commerical "turn-key" systems are only economical at sizes greater than 25 tons of dry matter/day. This means that farmer-constructed and operated systems are economical for confined-beef feedlots between 1,000 to 2,000 head without an effluent feed credit and about 300 head with an effluent feed credit of $70/ton. Commercial "turn-key" systems are only economical for confined feedlots larger than 8,000 head without effluent feed credit and between 1,000 to 2,000 head with an effluent feed credit of $70/ton. For dirt feedlots, the economical feedlot sizes must be at least twice as large because of the lower biodegradability of the manure and contamination with dirt and debris.

Table 1.—MARC calving difficulty score

Score	Degree of difficulty
1	No assistance
2	Minor difficulty-hand assistance
3	Fairly difficlut-calf jack necessary
4	Major difficulty
5	Caesarean
6	Abnormal position on presentation

Table 2.—U.S. MARC 1980 weak calf syndrome incidence (within calving difficulty)

	909 Heifers calving						
Difficulty score	1	2	3	4	5	6	Total
Weak calf deaths	8	0	30	8	4	3	53
Total numbers	464	27	282	45	45	45	909
Percentage	1.72	0	10.63	17.77	8.88	6.66	5.83
	4,494 Cows calving						
Difficulty score	1	2	3	4	5	6	Total
Weak calf deaths	83	1	11	1	1	5	102
Total numbers	4045	40	180	40	20	135	4,494
Percentage	2.05	2.50	6.11	2.50	5.00	3.70	2.26

Objectives.

1. Attempt experimental transmission of the disease to Caesarean-derived, colostrum-deprived gnotobiotic calves.
2. Attempt isolation of infectious agent(s) from experimentally and naturally infected calves.
3. Study multiplication of isolated agent(s) in body tissues of experimental or natural cases using labelled globulins from convalescent or hyperimune sera.
4. Observe and evaluate gross and microscopic tissue changes in experimental and natural infections.

Methodology

Specific Tasks.

1. Extracts of tissue suspensions from infected calves, or cultures of infectious agents, will be inoculated into gnotobiotic calves by one or more of the following routes, as necessary:
   a. I.M. and/or I.V.
   b. Respiratory tract (via aerosol or intratracheal injection).
   c. Duodenum.
   d. Intrauterine, at 8 mo gestation.
2. If unsuccessful, the above inoculations will be repeated following cold and/or corticosteroid-induced stress.
3. Agents visualization and isolation attempts will be made using several techniques. Direct isolation by physical procedures will start with fluids (joint, intestine, CNS fluid, tissue suspensions), which will be subjected to differential- and density-gradient centrifugation and, alternately, molecular seiving.

   Density gradient bands and concentrated fluids will be negatively stained and viewed by transmission electron microscopy (TEM). The same fluids will be used for cell culture and chick embryo inoculations. Cell cultures and embryonating egg fluids will be examined for hemagglutinins and also will be negatively stained and viewed by TEM. Unconventional cell culture propagation techniques would be utilized that would allow for isolation of agents, which are strongly cell-associated, or which depend on the host cell being in an unusual metabolic state or at below-normal temperature.

   Body fluids and tissue suspensions will be inoculated into several mycoplasma media, collectively, which are capable of supporting growth of the species thus far reported from cattle.
4. Acute and convalescent sera from natural and experimental infections will be collected when possible, as well as serum and colostrum from dams that have given birth to an affected calf. These will be used for immunochemical tests, such as the indirect fluorescent antibody technique (IFAT). The IFAT will be done with cryostat cut sections from affected calves.
5. As infectious agents are isolated, they will be adjusted into laboratory animals to produce hyperimmune sera for immunochemical tests.
6. Blood sera and body fluids will be checked by conventional serology for antibodies against infectious bovine rhinotracheitis, bovine viral diarrhea virus, and adenovirus type 5, as well as for any infectious agents isolated in this study.
7. Detailed records of herd history will be obtained when possible. These data will include nutritional factors, vaccination regimen, prevailing climatic conditions, husbandry practices, and genetic background. This information will be used to help determine whether there is any correlation between these factors and the incidence of Weak Calf Syndrome.

Table 3.—Causes of neo-natal deaths 1980 by week of birth[1,2]

			Major cause of death				
Week of calving season	Calves born	Total calves lost	Dystocia	Weak calf syndrome	Scours	Starvation	Exposure
4th	480	40	14	7	5	0	0
5th	815	54	15	1	2	2	1
7th	716	154	28	48	33	0	18
8th	437	79	8	32	12	13	0
9th	311	37	5	12	6	2	3
Total	2,759	364	70	112	58	17	22
Percentage		13.2	2.5	4.1	2.1	0.6	0.8

[1]Calving season begins February 21 and lasts for 12 weeks with approximately 1,200 heifers and 3,800 cows calving. Heifers calve 3 to 4 weeks before the cows.
[2]Figures for 6th week were not available.

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
NORTH CENTRAL REGION
Mid-Great Plains Area
Roman L. Hruska U.S. Meat Animal
Research Center
P.O. Box 166
Clay Center, Nebraska 68933